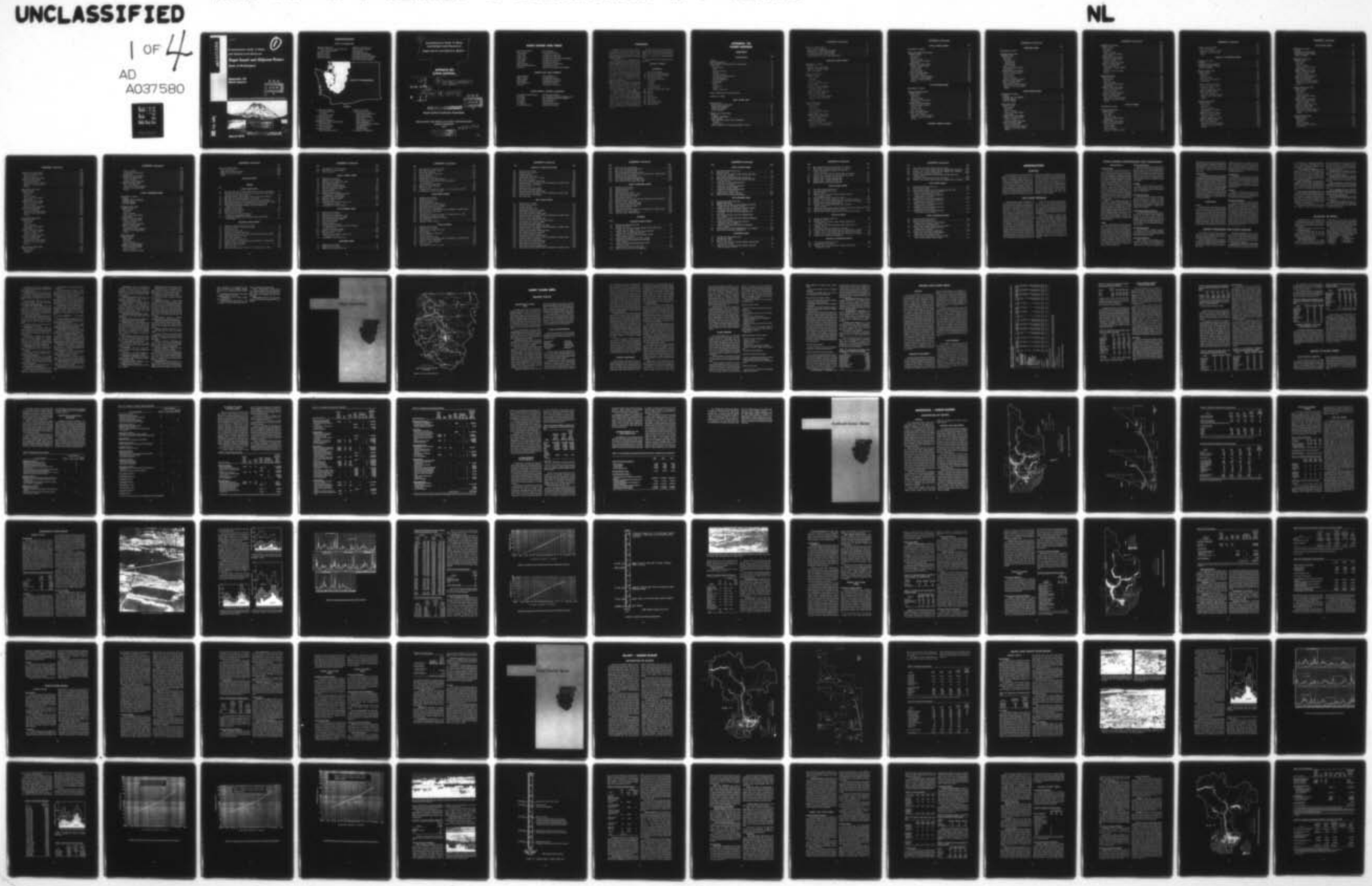
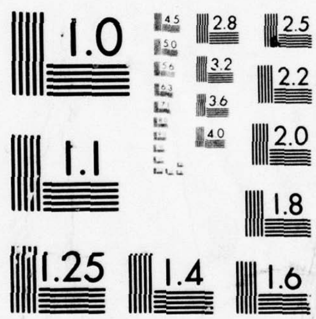
AD-A037 580 PACIFIC NORTHWEST RIVER BASINS COMMISSION VANCOUVER WASH F/G 8/6
COMPREHENSIVE STUDY OF WATER AND RELATED LAND RESOURCES. PUGET --ETC(U)
MAR 70 A T NEALE, S STEINBORN, L F KEHNE

UNCLASSIFIED NL

1 OF 4
AD
A037580






MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Comprehensive Study of Water and Related Land Resources

# Puget Sound and Adjacent Waters

State of Washington

Appendix XII
Flood Control



Puget Sound Task Force—Pacific Northwest River Basins Commission





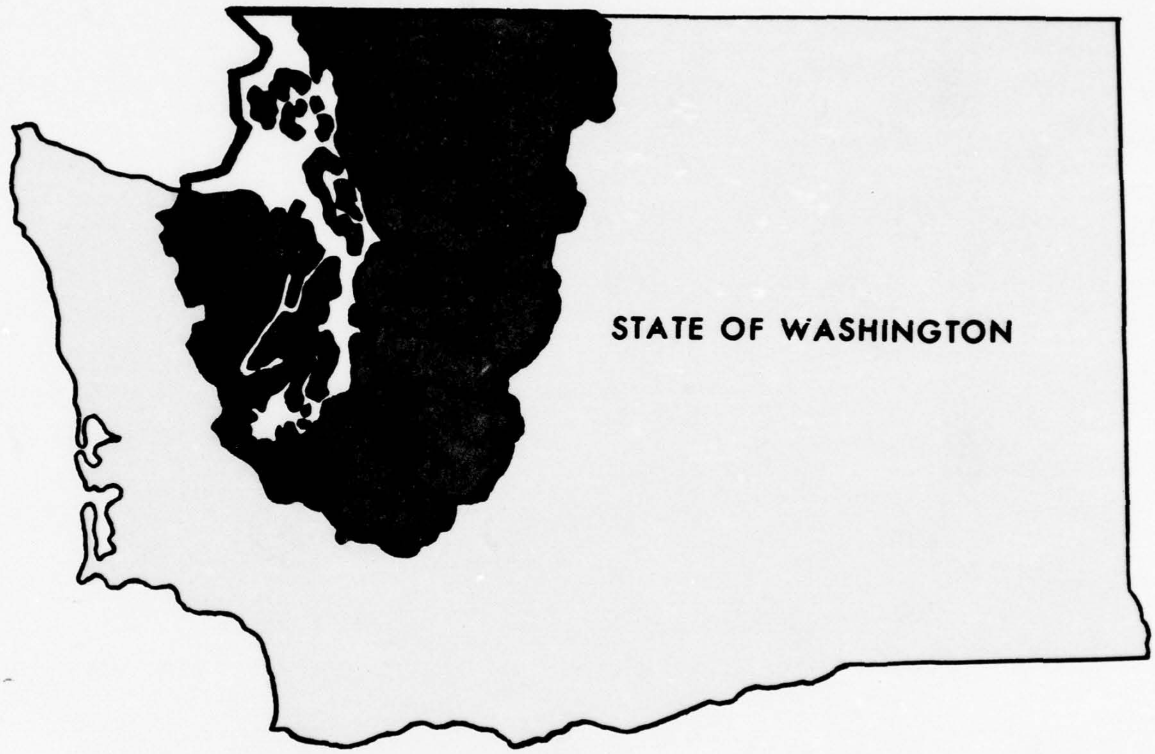


March 1970

# PARTICIPATION

## STATE OF WASHINGTON

Department of Agriculture
Department of Commerce & Economic Development
  Office of Nuclear Development
Department of Fisheries
Department of Game
Department of Health
Department of Highways
Department of Natural Resources
Department of Water Resources
Canal Commission
Oceanographic Commission
Parks and Recreation Commission
Planning and Community Affairs Agency
Soil and Water Conservation Committee
Water Pollution Control Commission




## FEDERAL

U.S. Department of Agriculture
  Economic Research Service
  Forest Service
  Soil Conservation Service
U.S. Department of the Army
  Corps of Engineers
U.S. Department of Commerce
U.S. Department of Health, Education & Welfare
  Public Health Service
U.S. Department of Housing and Urban Development
U.S. Department of Labor
  Bureau of Employment Security
Federal Power Commission
U.S. Department of the Interior
  Bonneville Power Administration
  Bureau of Indian Affairs
  Bureau of Land Management
  Bureau of Mines
  Bureau of Outdoor Recreation
  Bureau of Reclamation
  Federal Water Pollution Control Admin.
  Fish and Wildlife Service
  Geological Survey
  National Park Service
U.S. Department of Transportation

6

# Comprehensive Study of Water and Related Land Resources.

# Puget Sound and Adjacent Waters.

## APPENDIX ~~XII~~.
## FLOOD CONTROL.

Accession for
White Section ☑
Buff Section ☐
☐
Per Hr. on file
Availability codes
Dist. Avail. and/or special
A


10 Alfred T. Neale, Sydney Steinborn, Lewis F. Kehne, Ernest E. Allen
Francis L. Nelson


11 Mar 70 12 287p.



ORIGINAL CONTAINS COLOR PLATES: ALL DDC REPRODUCTIONS WILL BE IN BLACK AND WHITE.

**Flood Control Technical Committee**


PUGET SOUND TASK FORCE of the PACIFIC NORTHWEST RIVER BASINS COMMISSION
1970


410 072



LB

# PUGET SOUND TASK FORCE

| | |
|---|---|
| Alfred T. Neale, Chairman | State of Washington |
| Sydney Steinborn | U.S. Department of Army |
| Lewis F. Kehne | U.S. Department of Agriculture |
| Ernest E. Allen | U.S. Department of the Interior |
| Francis L. Nelson | U.S. Department of Health, Education and Welfare |
| Earl L. Phillips | U.S. Department of Commerce |
| I. Paul Chavez | Federal Power Commission |
| Robert E. Emerson | U.S. Department of Transportation |
| Horace W. Harding (Ex-Officio) | U.S. Department of Labor |
| John Merrill | Department of Housing and Urban Development |

## FORMER TASK FORCE MEMBERS

| | |
|---|---|
| John A. Richardson | State of Washington |
| Robert H. Gedney | U.S. Department of Army |
| Robert L. McNeil | U.S. Department of the Interior |
| Warren Hastings | U.S. Department of the Interior |
| Allan J. Meadowcroft | Federal Power Commission |
| Mark J. Pike | U.S. Department of the Interior |

## FLOOD CONTROL TECHNICAL COMMITTEE

| | |
|---|---|
| R. A. Skrinde, Committee Chairman | U.S. Army Corps of Engineers |
| G. M. Hastings | State of Washington, Department of Water Resources |
| H. P. O'Reilly | State of Washington, Department of Highways |
| J. E. Cummans | U.S. Geological Survey |
| R. J. Scofield | U.S. Forest Service |
| E. T. Fulkerson | U.S. Soil Conservation Service |
| J. F. Orsborn (Ex-officio) | Washington State University |

# FOREWORD

APPENDIX XII, Flood Control, contains a detailed report of the flood control component of the Comprehensive Water Resource Study of Puget Sound and Adjacent Waters. It is one of the technical appendices providing supporting data for the overall water resource study.

The *Summary Report* is supplemented by 15 appendices. Appendix I contains a Digest of Public Hearings. Appendices II through IV contain environmental studies. Appendices V through XIV each contain an inventory of present status, present and future needs, and the means to satisfy the needs, based upon a single use or control of water. Appendix XV contains comprehensive plans for the Puget Sound Area and its individual basins and describes the development of these multiple-purpose plans including the trade-offs of single-purpose solutions contained in Appendices V through XIV, to achieve multiple planning objectives.

The purpose of this appendix is to: (1) appraise the extent of present flooding and resulting flood damages in the Puget Sound Area; (2) determine the present and future flood control needs of the area; (3) present single-purpose means to meet these foreseeable short and long-term needs.

River-basin planning in the Pacific Northwest was started under the guidance of the Columbia Basin Inter-Agency Committee (CBIAC) and completed under the aegis of the Pacific Northwest River Basins Commission. A Task Force for Puget Sound and Adjacent Waters was established in 1964 by the CBIAC for the purpose of making a water resource study of the Puget Sound based upon guidelines set forth in Senate Document 97, 87th Congress, Second Session.

The Puget Sound Task Force consists of ten members, each representing a major State or Federal agency. All State and Federal agencies having some authority over, or interest in, the use of water resources are included in the organized planning effort.

The published report is contained in the following volumes.

## SUMMARY REPORT

## APPENDICES

I. Digest of Public Hearings
II. Political and Legislative Environment
III. Hydrology and Natural Environment
IV. Economic Environment
V. Water-Related Land Resources
  a. Agriculture
  b. Forests
  c. Minerals
  d. Intensive Land Use
  e. Future Land Use
VI. Municipal and Industrial Water Supply
VII. Irrigation
VIII. Navigation
IX. Power
X. Recreation
XI. Fish and Wildlife
XII. Flood Control
XIII. Water Quality Control
XIV. Watershed Management
XV. Plan Formulation

# APPENDIX XII
# FLOOD CONTROL

## CONTENTS

Page

### INTRODUCTION



### PUGET SOUND AREA

## CONTENTS—Continued



## NOOKSACK–SUMAS BASINS

## CONTENTS—Continued

### SKAGIT–SAMISH BASINS



### STILLAGUAMISH BASIN

## CONTENTS—Continued

Page

### SNOHOMISH BASIN



### CEDAR–GREEN BASINS

## CONTENTS—Continued

# CONTENTS—Continued

## CONTENTS—Continued

### WEST SOUND BASINS

## CONTENTS—Continued

## CONTENTS—Continued

## CONTENTS—Continued



## TABLES

### PUGET SOUND AREA



### NOOKSACK–SUMAS BASINS

## CONTENTS—Continued



### SKAGIT–SAMISH BASINS



### STILLAGUAMISH BASIN



### SNOHOMISH BASIN

## CONTENTS—Continued

## CONTENTS—Continued

## CONTENTS—Continued



### ELWHA–DUNGENESS BASINS



## FIGURES

Figure

### NOOKSACK–SUMAS BASINS

## CONTENTS—Continued

## CONTENTS—Continued



### CEDAR–GREEN BASINS



### PUYALLUP BASIN



### NISQUALLY–DESCHUTES BASINS

## CONTENTS—Continued



### WEST SOUND BASINS



### ELWHA–DUNGENESS BASINS

# INTRODUCTION

## PURPOSE

This appendix presents an assessment of flood problems in the Puget Sound Area, their causes and effects, and determines possible solutions as an element of the Comprehensive Water Resource Study of Puget Sound and Adjacent Waters. Characteristics of flooding were established by hydrologic studies and by field appraisals of damages. Existing flood control measures were examined and evaluated to establish their adequacy. Flood problems in the main river and the small watersheds were identified. From projections of economic development and from the frequency of flooding the future needs for control of floods and for management of the flood plain were determined. With these facts available, alternate plans for flood control with associated flood plain management were developed to satisfy the needs of the basin. This information was compiled for use in determining the role of flood control along with all other uses and control measures in the development of plans for the best use or combination of uses of water and related land resources to meet foreseeable short- and long-term needs of the basins. This appendix will make appropriate references to other appendices for basic information.

## THE FLOOD PROBLEM

The flood problem results from inundation of the flood plain by streamflows in excess of the capacity of the stream channel. An understanding of the formation and characteristics of the flood plain is essential to an understanding of this problem. The flood plain of a river is just as much a part of its natural course as the within bank channels which carry normal and low flows. This is an alluvial plain which is usually dry. The basic function of the river is to convey and discharge its load of water and naturally occurring sediment. To do this, a channel needs certain ratios of width, depth and velocity. If the channel is too wide for its depth, the velocity will be insufficient to carry the sediment; if too narrow, the river will attack its banks. The normal river tends towards equilibrium, which requires that the stream normally occupy only a portion of the valley bottom through which it meanders. Floods remake the valley bottom; they pour over the banks, abandoning the meandering channel of the stream and follow the general winding of the valley. River bars are scoured out or newly-formed and meandering loops are cut.

Floods are often accompanied by considerable loss of life and can cause great damage. These extreme flows can occur more than once during any year in the same river valley. One reason that floods are so destructive is that people tend to forget about past damages and hence develop and use flood plains adjoining the stream as though those disastrous events would never recur.

Not all flood problems are caused by major river floods. Severe damage to buildings, land resources and crops also result from overbank flooding of small streams and by excess precipitation. Small streams frequently flood because of localized conditions that occur more frequently and less predictably than those causing major river floods. However, flooding on tributaries can also be induced by major flood elevations on the main stem. The generally steeper gradient of small streams and their susceptibility to small intense storms that can occur nearly any time of the year, cause floods to be particularly conducive to erosion and production of sediment.

# FLOOD CONTROL OPPORTUNITIES AND CONSTRAINTS

## OPPORTUNITIES

### Upstream Storage

The function of a flood control reservoir is to store a portion of the flood flow in such a way as to minimize the flood peak at the area to be protected. This is accomplished by discharging all reservoir inflow until the discharge in the downstream channel is forecast to exceed the safe capacity or zero damage flow. Then the reservoir discharge is reduced to maintain the downstream flow at or below the safe capacity. During the recession, the stored water is released to recover storage capacity for the next flood. In an ideal case, the reservoir is situated immediately upstream from the protected area. If there is some appreciable distance between the reservoir and the area to be protected, substantial local inflow may make control to zero damage impossible. The reservoir would then be operated to control the flow to as low a peak as possible in the downstream reach.

While the most effective flood control is obtained from a reservoir located immediately upstream from the area to be protected, the dam and reservoir site may be undesirable due to valuable bottomland, relocation of existing facilities, or unfavorable foundation conditions. Storage sites located farther upstream, although they may not be as effective individually, require smaller dams and less valuable land and relocations and, therefore, may have greater economic feasibility. A system of upstream reservoirs may be necessary to provide effective flood reduction.

### Levees

Levees and floodwalls are essentially longitudinal dams or barriers erected along or parallel to a river or stream. A levee is an earth dike and constructed under the same criteria as a dam and of materials available at or near the site. Floodwalls are generally of masonry construction. Floodwalls and levees should be located so as to provide maximum protection while encroaching as little as possible on the natural floodway. A sufficient channel must be provided to transmit the design flow with a reasonable freeboard against wave action. Levees are also often constructed along salt water shorelines to prevent flooding from high tides.

### Channel Improvements

Reduction in flood stages on specific reaches of a river can often be achieved by merely improving the hydraulic capacity of the channel. Dredging of bars, deepening and widening of the channel, removal of brush and snags, straightening of bends and channel lining can be effective. Like levees, measures for improving channel capacity are essentially local protection measures and must be considered as items in an overall plan.

### Diversion

Diversion of flood waters from a basin to reduce flood discharges may be practical in some situations. This diversion could be to an adjacent river basin or into Puget Sound.

### Flood Plain Evacuation

Flood plain evacuation requires the purchase of flood plain lands and the relocation of existing facilities and developments. Evacuation of a flood plain can be effective in reducing future flood damages;however, major relocations would be expensive and may be unacceptable to a majority of the residents in the flood plain.

### Flood Fighting and Warning System

A good forecasting service is relatively inexpensive and can often provide adequate warnings sufficiently far in advance to permit orderly and complete evacuation. The success of such a plan depends heavily on the hydrologic characteristics of the river basin. Basins with small drainage areas are much more difficult to provide adequate warnings for than large basins.

### Watershed Management

Watershed treatment is designed to render the soil and vegetative cover more capable of absorbing and retaining a portion of the excessive rainfall until peak flood discharges have receded.

### Flood Plain Management

Future increases in flood damages can be minimized by flood plain zoning and regulations to insure that future development of flood plain lands is consistent with the level of flood protection pro-

vided. Land use controls do not attempt to reduce or eliminate flooding but are designed to mold the flood plain development in a manner that will lessen the damaging effects of floods. Zoning is the legal tool that is used to implement and enforce land use requirements.

### Flood Proofing

In some instances where buildings of high value are threatened by flooding, they can be individually floodproofed. Individual buildings sufficiently strong to resist the hydrostatic forces of the flood water are sometimes protected by building the lower stories (below the expected high water marks) without windows and providing some means of watertight closures for the doors. Thus, even though the building may be surrounded by water, the property within it is protected from damage, and many normal functions can be carried on. Although it is more simply and economically applied to new construction, floodproofing is also applicable to existing facilities that are structurally adequate.

## CONSTRAINTS

### Levees

Levees restrict the channel width by preventing flow on the flood plain and this results in increased stages in the leveed channel. Increased river stages could also occur upstream from the leveed reach. Downstream from the leveed area, peak flows could be increased because of the elimination of storage in the areas protected by the levees. The effect of levee construction on river stages depends upon the physical characteristics of the particular situation. Usually, however, levee construction would result in a general increase in flood stages along a river unless the eliminated valley storage is replaced by upstream flood control storage or increased channel capacity. Levee construction would have an adverse effect upon recreation values and fish and wildlife resources. Pumping facilities are often required to prevent ponding behind the levees.

### Channelization

Channelization could transfer flood damages downstream unless improvement begins at the mouth of the river or stream and extends upstream. Existing levees may have to be set back to provide the necessary floodway area. Channelization could have an adverse effect upon recreation values and fish and wildlife resources.

### Diversion

Diversion of floodwaters into another basin could result in a transfer of flood damages to that basin. Provisions must be made in the receiving basin to channelize and control the diverted flow.

### Fisheries and Recreation

Rivers and estuaries are important spawning and rearing areas for anadromous and resident fish. Estuaries serve as key rearing areas for anadromous fish. The streams, valley lands, and estuaries are important fish and wildlife and recreation resources. The avoidance of severe adverse impacts on these resources places restraints on structural measures for control of floods. Selected rivers or river segments are worthy of protection in a natural or near natural state for recreation use. Also the preservation and conservation of open space and riverfront lands near heavily populated areas require that flood control be held to a level which encourages the continuation of agricultural use in these areas.

# AGENCY PROGRAMS FOR FLOOD CONTROL

State, Federal, county and city governmental agencies are actively involved in programs related to flood control, flood emergencies, and flood plain management and information services.

A general description of agency responsibilities and services are covered in greater detail in Appendix II, Political and Legislative Environment. However, a brief resume of the agencies involved and the services they offer are:

**The State of Washington** assists in financing flood control plans and has responsibility to investigate and conduct engineering studies pertaining to flood control, to organize flood control districts and to review and approve all structures built in or along a floodway and across a flood plain.

**Soil Conservation Service, The U.S. Department of Agriculture** provides technical and financial assistance to local organizations including the State and its

political subdivisions, in planning and carrying out works of improvement for flood prevention and for the conservation, development, utilization and disposal of water in small watershed areas.

**The Forest Service, U.S. Department of Agriculture** carries out intensive land treatment and development programs aimed at minimizing flood hazards originating on National Forest lands. Assistance is given to State agencies and private forest owners to protect critical watersheds and to stimulate proper watershed management.

**Bureau of Reclamation, The Department of Interior** has authority to replace and repair irrigation facilities, both public and private, damaged by floods and to include flood control as a function in planning and construction of multiple purpose storage reservoirs.

**Corps of Engineers, Department of Army** Civil Works program embraces the investigations and works for flood control and related purposes which have been authorized by Congress for prosecution by the Department of Army under the supervision of the Corps of Engineers. The Corps of Engineers has been designated by the Congress as a Federal agency responsible for major flood control.

The program also includes flood plain management services to State and local governmental agencies, flood fighting, rescue operation services and the repair and restoration of damaged flood control works. The Corps also assists the Office of Emergency Planning by providing engineering and construction services during major disasters.

**Geological Survey, the Department of Interior** determines and publishes data on peak stages and discharges, runoff, and water quality.

**Weather Bureau, the Department of Commerce** is the responsible agency for river stage forecasts, storm tide warnings and the daily weather forecast for the area.

**The U.S. Department of Housing and Urban Development** makes planning grants to municipalities for land use studies that include use of flood plain lands.

**The U.S. Department of Commerce, Economic Development Administration** provides technical and financial assistance related to public works, flood plains and other redevelopment areas.

**Office of Emergency Planning** action on behalf of the President of the United States, provides disaster assistance.

**County and city governments** cooperate with state and Federal governments in providing flood protection and zoning of flood plain lands within their jurisdictional boundaries.

# GLOSSARY OF TERMS

ACRE-FOOT (ac-ft)–A unit commonly used for measuring the volume of water or sediment; equal to the quantity of water required to cover one acre to a depth of one foot and equal to 43,560 cubic feet or 325,851 gallons.

ALLUVIUM–Soil such as silt, sand or clay that has been deposited by water.

ANNUAL FINANCIAL COST–The sum of the annual equivalent of the fixed cost, the annual operation and maintenance costs, and the annual equivalent of major replacement costs.

BASE FLOW–See Base Runoff.

BASE RUNOFF–Sustained or fair weather runoff. In most streams, base runoff is composed largely of ground water effluent. The term base flow is often used in the same sense as base runoff. However, the distinction is the same as that between streamflow and runoff. When the concept in the terms base flow and base runoff is that of the natural flow in a stream, base runoff is the logical term.

BASIN–A geographic area drained by a single major stream. For the purposes of the Flood Control Appendix the Puget Sound and Adjacent Waters Area has been subdivided into the following nine basins and the Whidbey-Camano and San Juan Islands.

1. Nooksack-Sumas
2. Skagit-Samish
3. Stillaguamish
4. Snohomish
5. Cedar-Green
6. Puyallup
7. Nisqually-Deschutes
8. West Sound
9. Elwha-Dungeness

Flooding problems within the two island groups are not extensive and are discussed in Appendix XIV Watershed Management.

CHANNEL STORAGE–The volume of water at a given time in the channel or over the flood plain of the streams in a drainage basin or river reach. Channel storage is great during the progress of a flood event.

CONSTRUCTION COST–The total cost of construction, including real estate, engineering, design, administration and supervision.

CUBIC FEET PER SECOND (cfs)–A unit expressing rate of discharge. One cubic foot per second is equal to the discharge of a stream having a cross section of one square foot and flowing at an average velocity of one foot per second. It also equals a rate of 448.8 gallons per minute.

CUBIC FEET PER SECOND PER DAY (cfs-day)–The volume of water represented by a flow of one cubic foot per second for 24 hours. It equals 86,400 cubic feet, 1.983471 acre-feet, or 646,317 gallons.

DETRITUS–Material that results directly from rock disintegration or wearing away.

DISCHARGE–In its simplest concept, discharge means outflow; therefore, the use of this term is not restricted as to course or location and it can be used to describe the flow of water from a pipe or a drainage basin.

DISCHARGE, AVERAGE–The arithmetic average of the annual discharges for all complete water years of record whether or not they are consecutive. The term "average" is generally reserved for average of record and "mean" is used for average of shorter periods; namely daily mean discharge.

DIVERSION–The taking of water from a stream or other body of water into a canal, pipe, or other conduit.

DRAINAGE AREA–The drainage area of a stream, measured in a horizontal plane, which is enclosed by a drainage divide.

DRAINAGE DIVIDE–The line of highest elevations which separates adjoining drainage basins.

EROSION, BANK–Destruction of land areas located adjacent to a stream from the erosive action of high stream discharges.

EXCEEDENCE FREQUENCY–Percent of values that exceed a specified magnitude.

FLOOD–Any relatively high streamflow or an overflow or inundation that comes from a river or other body of water and causes or threatens damage.

FLOOD, ANNUAL–The highest peak discharge in a water year.

FLOOD FREQUENCY CURVE–A graph showing the number of times per 100 years, or the average interval of times within which a flood of a given magnitude will be equaled or exceeded.

FLOOD PEAK–The highest value of the stage of discharge attained by a flood; thus, peak stage or peak discharge. Flood crest has nearly the same meaning but, since it connotes the top of the flood wave, it is properly used only in referring to stage.

FLOOD PLAIN–A strip of relatively smooth land bordering a stream that has been or is subject to flooding. It is called a "living" flood plain if it is overflowed in times of high water, but a "fossil" flood plain if it is beyond the reach of the highest flood.

FLOOD PROBABILITY – See Probability Curve.

FLOOD, PROBABLE MAXIMUM–The largest flood for which there is any reasonable expectancy in the geographical region involved.

FLOOD ROUTING–The process of determining progressively downstream the timing and stage of a flood at successive points along the river.

FLOOD STAGE–The stage at which overflow of the natural banks of a stream begins to cause damage in the reach in which the stage is observed.

FLOOD, STANDARD PROJECT–A hypothetical flood that might result from the most severe combination of meteorological and hydrological conditions that are reasonably characteristic of the geographical region involved. The SPF is an important consideration for design of flood control structures.

FLOODWAY–The channel of a river or stream and those parts of the flood plains adjoining the channel which carry and discharge the floodwater or floodflow of any river or stream.

FREEBOARD–The vertical distance between a design maximum water level and the top of a structure. This space is utilized for safety.

GAGING STATION–A particular site on a stream, canal, lake or reservoir where systematic observations of gage height or discharge are obtained.

GROUND WATER–Water in the ground that is in the zone of saturation from which wells, springs and ground water runoff are supplied.

HYDROGRAPH–A graph showing stage, flow, velocity or other property of water with respect to time.

HYDROLOGIC CYCLE–A term denoting the circulation of water from the sea, through the atmosphere, to the land; and, thence, with many delays, back to the sea by overland and subterranean routes, and in part by way of the atmosphere without reaching the sea.

MAJOR REPLACEMENT COSTS–Costs of replacement of rehabilitation of major structural or equipment items within the project life.

NONSTRUCTURAL MEASURES–Measures for managing, utilizing, or controlling water and related lands without structural development to achieve the desired objective. Such measures include flood plain zoning, flood warning systems, legal restraints, and preservation, as well as the more common land management measures.

OPERATION AND MAINTENANCE COSTS–Average annual costs of project operation and normal maintenance.

OPPORTUNITIES–Potential developments or potential utilization capable of being realized.

PRECIPITATION–As used in hydrology, precipitation is the discharge of water, in liquid or solid state, out of the atmosphere, generally upon a land or water surface. It is the common process by which atmospheric water becomes surface or subsurface water. The term "precipitation" is also commonly used to designate the quantity of water that is precipitated.

RAIN SHADOW–The effect of a high mountain range such as the Olympic Mountains on maritime air masses resulting in relatively low precipitation in the area sheltered by the mountains.

RECURRENCE INTERVAL–The average number of years within which a given event will be equaled or exceeded.

RESERVOIR–A pond, lake or basin, either natural or artificual, for the storage, regulation, and control of water.

RESERVOIR, MULTIPLE–PURPOSE–A reservoir planned to serve more than one purpose.

RESERVOIR, RETARDING–Ungated reservoir for temporary storage of floodwater. Sometimes called a detention reservoir.

RESERVOIR, SINGLE–PURPOSE–A reservoir planned to serve only one purpose.

RIPARIAN–Pertaining to the banks of streams, lakes or tidewater.

RIVER REACH–Any defined length of a river.

RUNOFF–That part of the precipitation that appears in surface streams. It is the same as streamflow unaffected by artificial diversions, storage or other works of man in or on the stream channels.

RUNOFF, AVERAGE ANNUAL–Average of water year runoff in inches or acre-feet for the total period of record.

SEDIMENT–Fragmental or clastic mineral particles derived from soil, alluvial, and rock materials by processes of erosion; and transported by water, wind, ice, and gravity. A special kind of sediment is generated by precipitation of solids from solution (i.e., calcium carbonate, iron oxides). Excluded from the definition is vegetation, wood bacterial and algal slimes, extraneous light-weight, artificially made substances such as trash, plastics, flue ash, dyes, and semi-solids.

STORAGE–Water naturally or artificially impounded in surface or underground reservoirs.

STORAGE CAPACITY, ACTIVE (USABLE)–The volume normally available for release from a reservoir below the stage of the maximum controllable level (total capacity less inactive and dead capacity).

STORAGE CAPACITY, DEAD–The volume of a reservoir below the sill or invert of the lowest outlet.

STORAGE CAPACITY, EXCLUSIVE FLOOD CONTROL–The space in reservoirs reserved for the sole purpose of regulating flood inflows to abate flood damage.

STORAGE CAPACITY, SURCHARGE–The volume of water in a reservoir between the designed maximum water surface elevation and normal pool elevation for either a gated or ungated spillway.

STORAGE CAPACITY, TOTAL–The total volume of a reservoir exclusive of surcharge.

STREAM–A general term for a body of flowing water. In hydrology, the term is generally applied to the water flowing in a natural channel as distinct from a canal. More generally, as in the term stream gaging, it is applied to the water flowing in any channel, natural or artificial.

STREAMFLOW–The discharge that occurs in a natural channel. Although the term discharge can be applied to the flow of a canal, the word streamflow uniquely describes the discharge in a surface stream

course. Streamflow is a more general term than runoff, as streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

STREAMFLOW REGULATION–The artificial manipulation of the flow of a stream.

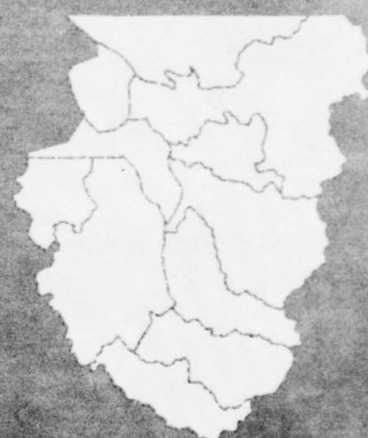
WATERSHED–A term to signify drainage basin or catchment area.

WATER TABLE–The upper surface of a zone of saturation. No water table exists where that surface is formed by an impermeable body.

WATER YIELD–Runoff, including ground water outflow that appears in the stream, plus ground water outflow that leaves the basin underground. Water yield is the precipitation minus the evapotranspiration.

ZERO DAMAGE FLOW–The maximum flow a stream can carry without causing overbank flow and damages.

# Puget Sound Area



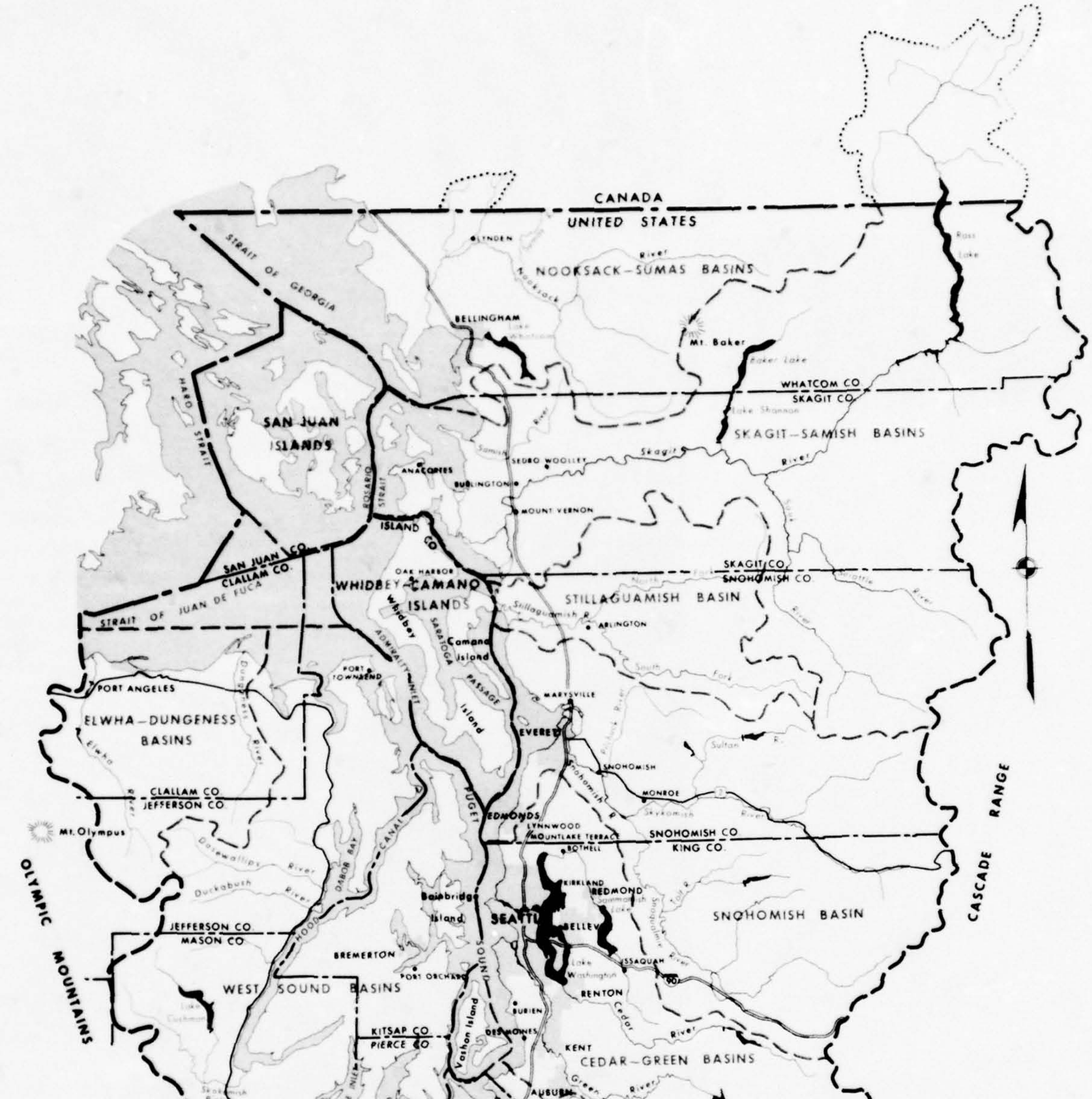



**FIGURE 2-1. Basins in the Puget Sound Area**

# PUGET SOUND AREA

## PRESENT STATUS

### DESCRIPTION OF STUDY AREA

The Puget Sound Area lies in northwestern Washington, between the crests of the Cascade and Olympic Mountains as shown on Figure 2-1. Its 13,500 square miles of land, lying in a setting of forests and mountains has a terrain varying from bare glacier covered peaks through forest covered slopes to fertile farm lands and urban centers on river deltas and shore lands. There are about 2,500 square miles of nearly landlocked salt water that have 10 major ports with deep water access to the Pacific Ocean. Twenty rivers flow into Puget Sound and its adjacent waters.

In the Cascade Range to the east, the higher ridges generally reach an altitude of 8,000 feet in the north and 5,000 feet in the south. Rising prominently above this ridge line are the dormant volcanoes of Mount Baker (10,778 feet); Glacier Peak (10,541 feet); and Mount Rainier (14,410 feet).

The Olympic Mountain Range to the west is generally lower in altitude than the Cascade Range. The sharp peaks and ridges that characterize this mountain range reach altitudes of 6,000 feet.

These mountain ranges protect the Puget Sound Area from the cold Arctic air and the ocean storms. Maritime air which enters from the south has a moderating influence on the climate in both winter and summer. Mean annual precipitation varies from less than 20 inches in the lowlands of the Elwha Dungeness Basins to 120 to 180 inches along the upper reaches of the Cascade Mountains. Seventy-five percent of the precipitation occurs in the 6-month period, October through March, with winter precipitation generally falling as rain below 1,500 feet altitude, as snow or rain between 1,500 and 2,500 feet, and as snow at the higher altitudes.

Although extremely warm temperatures have been recorded as high as 95° F to 100° F in the lower valleys, high temperatures usually range from 85° F to 90° F, 5 to 15 days per year. Mean temperatures range from 70° F during the summer to 30° F to 40° F during the winter. Additional climatic data is given in Appendix III, Hydrology and Natural Environment.

For study purposes, the area is divided into nine basins and two island groups. However, the two island groups, San Juan and Whidbey-Camano Islands, are not covered by this appendix because overbank flooding is not a serious problem. The reader is referred to Appendix XIV, Watershed Management, for flood problems in these two island groups.

### FLOOD CHARACTERISTICS

Of the many rivers, large and small, flowing into Puget Sound and its adjacent marine waters, the following ten river basins discharge an average of 84% of the total runoff:

| | |
|---|---|
| Nooksack River | Green River |
| Skagit River | Puyallup River |
| Stillaguamish River | Nisqually River |
| Snohomish River | Skokomish River |
| Cedar River | Elwha River |

Each river basin is generally characterized by narrow mountain valleys with steep gradients, opening onto broad valleys or delta plain lowlands. Most of the agricultural and urban developments are found in these lowlands and adjacent uplands.

The greatest threat of major stream flooding occurs during the months of October through March. Floodflows are primarily rainwater, often increased by low-level snowmelt. Because the majority of the rivers have relatively steep gradients they can rise to flood stage with very little warning to headwater

areas. Almost without exception, the damaging high-water is the winter flood which is characterized by high magnitudes and short durations. High water periods occur in the fall or winter coinciding with the period of maximum precipitation and in the early summer when a seasonal rise in temperature melts snow in the mountains. Winter floods normally last two or three days with the river discharges increasing from a relatively low base flow to near flood stage in a few hours. Occasionally, extreme spring highwater is experienced on rivers with high altitude drainage basins. These can occur during April to June, as a result of heavy spring or early summer precipitation and exceptionally high temperatures which cause melting of a deep snowpack. Climatic differences because of unequal elevations in the watersheds also cause varying flow patterns.

Prevailing winds during the winter months bring moisture laden air into the area from the Pacific Ocean. The "rain shadow" effects of the Olympic Mountains extend over the northern central portion but have little or no influence at higher elevations. Maximum precipitation in the eastern portion occurs as moisture is released from air rising across the Cascade Range. Precipitation normally falls as snow in the higher mountains and remains on the slopes until the spring and summer months. Precipitation in the intermediate and lower elevations normally occurs as rain or snow which melts rapidly. Prevailing northwest winds in the summer are relatively cool and inhibit melting of the snowpack at higher elevations.

Conditions conducive to floodflows exist when several storms in succession pass inland creating a high degree of saturation of the soil, increasing the moisture content of the snowpack and raising the rivers to bankful condition. If an intense storm with a high rate of precipitation then occurs over the basin, extreme floodflows are inevitable. The combination of rising temperature and heavy rainfall causes rapid low-level snowmelt which adds to the runoff.

## EXISTING CONDITIONS

Existing flood control measures consist of upstream storage, levees, and channel improvements. Levees have generally been constructed along the lower river reaches to protect against high tides from Puget Sound. Other levees along various upstream reaches protect against high flood stages in the river. Existing levees were constructed primarily to prevent spring flooding of agricultural lands. Flood storage is provided by Ross Dam on the Skagit River, Howard A. Hanson Dam on the Green River and Mud Mountain Dam on the White River, a tributary to the Puyallup. Hydroelectric power and water supply storage projects on the Skagit, Cedar, Nisqually, Skokomish and Elwha River systems also provide some incidental flood reduction. Channel improvement works for flood control have been constructed on the Sammamish River, the lower Cedar River, and the lower Puyallup River.

Except for the Green and Puyallup River Basins, the level of flood protection is far below the minimum standard required for any reasonable degree of urban and suburban development. The lower Puyallup River Basin is protected against floods with recurrence interval of once in 200 years by Mud Mountain Dam and Reservoir and channel improvements along the lower river. In the Green River Basin the Howard A. Hanson Dam and Reservoir has sufficient storage to completely control the runoff at the project for a 600-year flood.

Levee systems are providing the major means of protection against floods in agricultural lands. These levees are mostly the uncoordinated efforts of local diking and drainage districts and were originally constructed to prevent spring flooding. The degree of protection afforded is generally of 2- to 8-year frequency. As a result, protected agricultural lands are still subject to frequent flooding from the larger winter floods. Optimum usage of agricultural lands are thus restricted, depending partly on the rapidity with which saturated lands can be drained and the debris and sediment deposits removed.

The sediment load in the rivers of the Puget Sound Area also present special problems. The river deposits sediment where the gradient of the river flattens from the steep mountainous area to the flat flood plain. As a result the upper reaches of the flood plains are subject to frequent changes in river channel location and direction, and bank erosion and loss of valuable farm lands are typical occurrences. The continued deposition also adds to overbank flooding conditions.

Throughout most of the Puget Sound Area, the U.S. Weather Bureau provides river forecasts. The Weather Bureau Forecast Office, Seattle, Washington, is responsible for the program in the Puget Sound Area. The Seattle office maintains and collects hydrometeorologic reports from a network of sub-

stations and these reports are available on a year-around basis for many key river and weather stations. Flood forecasts and warnings are given wide dissemination. Close cooperation is maintained with state, county and city officials; with Federal agencies (especially the Corps of Engineers, U.S. Geological Survey, and Office of Emergency Planning); American Red Cross, County Civil Defense, County Flood Control authorities, and public and private utilities. Residents of the flood plains and the general public receive warnings through telephone, television, radio and the newspaper media.

Limited steps have been taken in the use of flood plain regulations as a means of controlling and reducing flood damages. Flood plain information reports, which present detailed information on flood characteristics and hazards, have been prepared by the Corps of Engineers for the Nooksack, Sumas, Skagit, Stillaguamish and Snohomish River Basins. These have furnished a basis for apprising local governments of the flood hazards in these areas and the desirability of instituting flood plain regulations. To date, Skagit, Snohomish and King Counties have initiated action in this respect. Similar measures are under consideration in several counties throughout the area.

## FLOOD DAMAGES

In the Puget Sound Area, the flood plain constitutes approximately three percent of the total available land area of 13,500 square miles. This relatively small area provides the bulk of the land readily suitable for agriculture and for some industrial uses and offers many advantages that tend to compensate for the risk of flood damages. Alluvial soils in the flood plains form some of the richest agricultural land in the area. The flood plain also contains some of the most extensively developed land including transportation facilities, communities, and industrial developments.

Existing regulation works afford only limited protection in the area and as a result heavy damages are still sustained in most of the region's flood plain lands.

Detailed appraisal has been made of the damages incurred throughout the basin as a first step in determining flood control needs. In agricultural areas, sample areas representative of each farm type were appraised and unit damage amounts were applied to the total cropland acreage of each type. Some relatively small areas, such as berry farms and nurseries were individually classified and appraised. Urban damages were estimated from detailed appraisals of sample residential and commercial blocks. Estimates were then made of the total damages within the particular community. The effects on bridges, levees, highways, railroads and other special items were individually appraised.

Damages were classified in several categories, described as follows:

Agricultural category includes:

Drowning of grasses and other plants, and costs of replanting.

Loss of crops.

Loss of livestock and loss due to dairy enterprise interruption.

Erosion of banks and fallow ground.

Leaching of fertilizer and costs of reapplication.

Infestation by weeds.

Damage to fences.

Deposition of sand, gravel and drift material and cost of removal.

Temporary loss of use of pastures because of ground saturation, erosion, debris deposits and continued floodwater occupation.

Sheet erosion.

Buildings and equipment category includes:

Shifting and settling of foundations.

Damp rot in timber.

Buckling of floors and walls.

Electrical shorts.

Damage to yards, sidewalks and landscaping.

Rusting and silting of vehicles, tools, and appliances.

Damage and loss of furnishings.

Transportation facilities category includes:

Erosion, or undermining by saturation, of rail and roadway embankment, shoulders and surfacing.

Financial losses caused by traffic interruptions and detours.

Utilities category includes:

Damages to power, communications, water supply, sewage and other facilities.

Diking, drainage and irrigation systems category includes:

Levee systems damaged by erosion, overtopping and seepage.

Drainage and pumping systems, and irrigation systems, damaged by erosion and siltation.

Parks and fish hatchery category includes:

Park grounds and facilities damaged by siltation, and deposition of debris and erosion.

Undermining of improvements such as to buildings and equipment.

Damages to fish hatcheries include loss of fish in hatching ponds, loss of eggs, and damage to buildings, contents and facilities.

Appraisals have not been made for losses due to flooding in connection with fish spawning and rearing areas and to wildlife habitats. Flood flows cause substantial direct damage to resident and anadromous fish populations by disturbing the gravel bars and washing implanted eggs from their protective nests into violent waterflow and shifting gravel. Indirect losses result from piling gravel onto large bars above normal water level forcing fish to over-utilize remaining smaller gravel beds. Soil erosion and the subsequent deposition of silt and sand clog gravel and smother eggs because of inadequate intragravel water flows necessary to carry oxygen to the eggs and remove metabolic wastes. Peak flows occurring after the juvenile fish have emerged from the gravel result in high losses from stranding in the flood plain areas. High flows also destroy essential stream habitat and food producing areas.

Flood relief category includes:

Expenses for refuge care, flood rescue and patrol, flood fighting, sanitation and health measures.

Employee and business losses category includes:

Loss of wages and net profit by business concerns. The appraisals of damages sustained by actual past floods was supplemented by estimates of damages that would be sustained by floods throughout a wide range of magnitudes. The estimates were adjusted as necessary to reflect damages that would be sustained under current flood plain developments and price levels (1966) and then were converted to annual damage determinations in the following manner:

**a. Discharge-Frequency Relationship**—Curves showing discharge frequencies were developed for each damage area. The curves were developed from existing records, historical reports, comparison of areas and runoff characteristics and correlation of recorded discharges. Details of these derivations are shown in the discussion concerning each basin in this appendix and also in Appendix III, Hydrology and Natural Environment.

**b. Discharge-Damage Relationship**—Discharge-damage curves for each type of damage, such as residential, commercial, industrial and agriculture were prepared by plotting damages from past floods, adjusted to 1966 conditions against the corresponding flood discharges through the respective areas and fitting a curve to these points.

**c. Damage-Frequency Relationship**—Curves showing damage-frequency relationship were prepared by graphical correlation by quadrant plotting of the discharge damage and discharge-frequency curves for existing conditions and also for conditions of various plans for improvements and degree of protection.

**d. Average Annual Damage**—The area under the damage frequency curve, which is the summation of the product of the damage associated with floods of varying magnitude and the corresponding frequency, comprises the annual damage.

The estimated annual damages in the region, *under 1966 prices and conditions of development*, amount to more than 7 million dollars as shown in Table 2-1.

About $5,300,000 or 75 percent of the damages occur in the Skagit-Samish and Snohomish Basins. Another $850,000 or 12 percent of the damages occur in the Nooksack-Sumas Basins. More detailed data, by individual basins, are presented in the following sections of this Appendix.

**TABLE 2-1. Puget Sound Area—average annual damages by basin—1966 prices and conditions**

| Basin | Damages |
|---|---|
| Nooksack-Sumas Basins | $ 853,000 |
| Skagit-Samish Basins | 3,020,000 |
| Stillaguamish Basin | 256,000 |
| Snohomish Basin | 2,310,000 |
| Cedar-Green Basins | 447,000 |
| Puyallup Basin | 100,000 |
| Nisqually-Deschutes Basins | 57,000 |
| West Sound Basins | 51,000 |
| Elwha-Dungeness Basins | 28,000 |
| Total | $7,122,000 |

# PRESENT AND FUTURE NEEDS

## GENERAL

A total of 747,000 acres are found subject to floodwater damages at least once in 100 years from excess precipitation and other causes. About 276,800 acres of the total are subject to damages by overbank flooding of major streams, in addition to other sources of damaging water. Flooding other than main-stem overbank flooding is discussed in Appendix IV, Watershed Management. This Appendix discusses flooding and flood protection and damage reduction from overbank flooding of major streams. The estimated average annual flood damages of $7,122,000 in the Puget Sound Area indicate the need for additional flood protection and flood plain management in the flood plains of the various river basins. The flood damages occur in all river basins but are most severe in the Nooksack, Skagit-Samish and Snohomish Basins. Only portions of the Green and Puyallup River Basins have a level of flood protection above the minimum standard required for any reasonable degree of urban and suburban developments. This protection results from flood control storage in Howard A. Hanson Reservoir on the Green River and Mud Mountain Reservoir on the White River, a major tributary to the Puyallup River. Levee systems provide the major means of protection against floods for agricultural lands. The frequency of protection varies from once in 2 years to about once in 8 years. As a result, these agricultural lands are subject to frequent flooding during the winter flood seasons. Continued growth in population, social, and economic pressures are increasing the need for suitable lands for intensive development for agriculture, and other uses.

## ECONOMIC ENVIRONMENT

Present economic development and projections to 1980, 2000 and 2020 in the Puget Sound Area are discussed in detail in Appendix IV, Economic Environment. The reader is referred to the "Introduction" of Appendix IV for definition of The Puget Sound Economic Area. Table 2-2 presents a synopsis of this information. The population is expected to increase from the 1963 population of 1.9 million to 2.7 million in 1980 to 4.3 million in the year 2000 and to 6.8 million in the year 2020. Gross regional product in 1980 measured in 1963 dollars is estimated to be 11.4 billion dollars, or twice that of 1963. The gross regional product in the year 2000 is estimated to be 27 billion dollars and is expected to increase to 68 billion dollars in the year 2020. Employment is expected to increase from 662,000 in 1963 to 2.4 million in 2020.

The largest growth is expected to occur in the Central Division with population estimated to be over 6 million by the year 2020. Population in the North Division is expected to exceed 340,000 by the year 2020 and in the West Division to approach a quarter of a million people by the year 2020. The present economic upsurge in the Central Division will continue with aerospace leading the industrial activity. The North Division's increase in economic activity is expected to occur primarily in wholesale and retail trade, services, and primary metals. The West Division's growth is expected to result from increases in the pulp and paper industry and in State Government in Thurston County. Projected employment for the period 1980 to 2020 for the Puget Sound Area and for the North, Central and West Divisions is shown in Table 2-2.

## LAND DEMANDS

An estimated 6.8 million people are expected by the year 2020 in the Puget Sound Area. The Central Division which contains the Everett-Seattle-Tacoma metropolitan areas accounted for 85 percent of the population in 1963. By the year 2020 the portion of the population expected to be located in the Central Division will rise to 92 percent. The importance of the Central Division to the study area is attributable to the dynamic economic activity which is expected to provide excellent employment opportunities. A comparison of the population density per square mile also indicates the urban character of the Central Division. Table 2-3 shows the anticipated change in population density in the Economic Study Area.

**TABLE 2-2. Puget Sound Economic Area—1963 and projected employment by major industry, population and gross regional product (population and employment in 000's)**

| No. | Employment by Industry | North Division 1963 | North Division 1980 | North Division 2000 | North Division 2020 | Central Division 1963 | Central Division 1980 | Central Division 2000 | Central Division 2020 | West Division 1963 | West Division 1980 | West Division 2000 | West Division 2020 | Puget Sound Economic Area 1963 | Puget Sound Economic Area 1980 | Puget Sound Economic Area 2000 | Puget Sound Economic Area 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Agri., For., Fish., & Mining[1] | 7.1 | 6.0 | 5.3 | 4.7 | 14.0 | 9.9 | 6.6 | 4.8 | 2.6 | 2.3 | 1.6 | 1.5 | 23.7 | 18.2 | 13.5 | 11.0 |
| 2 | Food & Kindred Products | 2.4 | 2.2 | 2.5 | 2.8 | 12.6 | 15.9 | 18.7 | 21.0 | .9 | 1.4 | 1.6 | 1.8 | 15.9 | 19.5 | 22.9 | 25.6 |
| 3 | Lumber & Wood Products[2] | 2.1 | 1.5 | .4 | .1 | 13.1 | 5.2 | 1.8 | .6 | 4.4 | 1.7 | .6 | .2 | 19.7 | 8.3 | 2.8 | .9 |
| | | | (2.7) | (2.3) | (1.9) | | (10.7) | (9.3) | (8.2) | | (3.6) | (3.1) | (2.8) | | (17.0) | (14.7) | (12.6) |
| 4 | Paper & Allied Products[2] | 1.1 | 2.3 | 2.5 | 2.0 | 6.8 | 8.5 | 9.3 | 7.2 | 1.5 | 3.8 | 4.1 | 3.2 | 9.4 | 14.7 | 15.9 | 12.4 |
| | | | (1.2) | (1.3) | (1.1) | | (10.7) | (6.0) | (5.1) | | (3.4) | (3.6) | (3.1) | | (10.3) | (10.9) | (9.3) |
| 5 | Chemicals | •[3] | • | • | • | 2.2 | 1.8 | 1.3 | .9 | .1 | • | • | • | 2.3 | 1.9 | 1.4 | 1.0 |
| 6 | Petroleum Refining | 1.0 | 1.2 | 1.2 | 1.2 | .2 | .2 | .2 | .2 | • | • | • | • | 1.2 | 1.3 | 1.4 | 1.3 |
| 7 | Stone, Clay & Glass | .4 | .5 | .7 | .8 | 3.3 | 4.5 | 5.8 | 7.1 | .1 | .1 | .1 | .1 | 3.8 | 5.0 | 6.5 | 8.0 |
| 8 | Primary Metals | • | 3.5 | 4.2 | 4.8 | 4.1 | 3.8 | 4.5 | 5.1 | • | • | • | • | 4.1 | 7.3 | 8.7 | 9.9 |
| 9 | Other Non-Durable Mfg. | .7 | .5 | .7 | .8 | 13.8 | 19.0 | 24.3 | 29.8 | .5 | .2 | .3 | .3 | 15.1 | 19.7 | 25.2 | 30.9 |
| 10 | Other Durable Mfgrs. | .8 | 1.3 | 2.8 | 5.9 | 85.2 | 174.0 | 377.1 | 780.1 | .2 | .3 | .7 | 1.5 | 86.2 | 175.7 | 380.7 | 787.4 |
| 11 | Trans., Com., & P.U. | 2.1 | 2.7 | 2.3 | 1.8 | 36.7 | 32.1 | 26.3 | 20.6 | 1.5 | 1.4 | 1.2 | .9 | 40.2 | 36.2 | 29.7 | 23.3 |
| 12 | Whsle. & Retail Trade | 8.3 | 11.1 | 16.0 | 22.0 | 125.3 | 187.0 | 269.8 | 371.5 | 6.3 | 4.5 | 6.5 | 9.0 | 140.0 | 202.6 | 292.3 | 402.4 |
| 13 | Services | 8.4 | 10.0 | 16.9 | 27.3 | 128.3 | 214.2 | 362.0 | 584.0 | 7.3 | 5.9 | 9.9 | 16.0 | 144.0 | 230.1 | 388.8 | 627.3 |
| 14 | Construction | 2.8 | 2.8 | 3.7 | 4.5 | 36.3 | 49.6 | 64.2 | 79.4 | 2.1 | 2.0 | 2.7 | 3.3 | 41.2 | 54.5 | 70.5 | 87.2 |
| 15 | Government | 8.3 | 12.3 | 19.0 | 28.0 | 97.2 | 147.5 | 227.9 | 336.1 | 10.2 | 18.3 | 28.3 | 41.7 | 115.8 | 178.1 | 275.1 | 405.8 |
| | Total Employment[4] | 45.5 | 57.9 | 78.2 | 106.7 | 579.1 | 873.2 | 1399.8 | 2248.4 | 37.7 | 41.9 | 57.6 | 79.5 | 662.6 | 973.1 | 1535.4 | 2434.4 |
| | Total Population | 151.0 | 185.5 | 249.9 | 341.5 | 1603.0 | 2418.9 | 3882.1 | 6235.5 | 116.0 | 122.5 | 169.5 | 232.4 | 1870.0 | 2726.9 | 4300.5 | 6809.4 |
| | Gross Regional Product (millions 1963 $'s) | $369 | 848 | 1,800 | 3,977 | 5,172 | 10,022 | 24,569 | 62,061 | 290 | 498 | 1,066 | 1,329 | 5,830 | 11,358 | 27,436 | 68,248 |

1 Underlined industries are large users of water.

2 Employment in ( ) represents projections made by Forest Service, U.S. Department of Agriculture which were made available after completion of the input-output study as found in Exhibit D. The Forest Service projections will be utilized for planning purposes.

3 • Less than 50 employees.

4 Figures may not add to totals due to rounding.

Source: Appendix IV, Economic Environment.

**TABLE 2-3. Puget Sound Economic Area—population density per square mile 1963-2020**

| Division | Square Miles[1] | 1963 | 1980 | 2000 | 2020 |
|---|---|---|---|---|---|
| North | 4,252 | 35.5 | 43.6 | 58.8 | 80.3 |
| Central | 6,298 | 254.5 | 384.1 | 616.4 | 990.1 |
| West | 5,234 | 22.2 | 23.4 | 32.4 | 44.4 |
| Total Economic Area | 15,784 | 118.4 | 172.8 | 272.5 | 431.4 |

[1] Based on county areas in 1963 City and County Data Book, 1967, U.S. Department of Commerce.

Source: Appendix IV, Economic Environment.

Population projections by river basins shown in Table 2-4, indicate that the greatest concentration will continue to be in the Cedar-Green Basin, followed by the Puyallup and Snohomish Basins. Future land demands can be expected to be greatest in and adjacent to existing towns and cities of each of the basins. Reduction in lands available for agriculture will require more intensive utilization of acreages remaining for this purpose. Additional protection from flooding will therefore be required for urban and industrial development and to support increased agricultural productivity.

**TABLE 2-4. Puget Sound Area—population projections by river basins (in thousands)**

| Basins | 1963 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Nooksack-Sumas | 74.6 | 91.6 | 123.5 | 168.7 |
| Skagit-Samish | 53.8 | 64.2 | 86.5 | 118.2 |
| Stillaguamish | 17.6 | 30.2 | 48.5 | 77.8 |
| Snohomish | 178.2 | 302.7 | 485.8 | 780.3 |
| Cedar-Green | 976.9 | 1,479.0 | 2,375.7 | 3,816.3 |
| Puyallup | 324.5 | 449.8 | 721.0 | 1,157.7 |
| Nisqually-Deschutes | 69.6 | 74.9 | 104.5 | 146.5 |
| West Sound | 124.2 | 175.0 | 274.1 | 432.7 |
| Elwha-Dungeness | 28.3 | 29.8 | 41.0 | 56.6 |
| Whidbey-Camano Islands | 19.9 | 26.9 | 36.2 | 49.5 |
| San Juan Islands | 2.6 | 2.8 | 3.7 | 5.1 |
| Puget Sound Area Totals | 1,870.0 | 2,726.9 | 4,300.5 | 6,809.4 |

Source: Appendix IV, Economic Environment.

## FLOOD DAMAGES UNDER FUTURE CONDITIONS

Future flood damages may be expected to increase in proportion to the increase in economic development on the flood plains if additional protection is not provided. In order to evaluate the magnitude of the future flood problem and the requirements for protective measures, estimates were made of the level of flood damages that would be sustained in future periods based on the projected population and economic growth in each of the region's river basins.

There is a high correlation between flood damages and the value of property and economic activity in the area of property inundation. In the future it may be expected that damages will increase in direct proportion to increases in property values and business, residential, and public developments in the flood plain. Determination of future damages has therefore been based on projections of economic indicators pertinent to these factors. Trends in population growth, income and expenditures, and land use patterns, all of which would have a direct effect on the magnitude of future flood damages, were projected for each flood plain. Separate estimates were made of agricultural and non-agricultural damages. The non-agricultural component was further broken down into several categories of property. Economic indexes appropriate to each category were then applied in determining increased future damages.

### Agriculture

Growth in agricultural flood damages was based on projections of production and value of major agricultural products. These projections, made by the Economic Research Service, U.S. Department of Agriculture, for the Puget Sound Area, are found in Appendix IV, Economic Environment. Major product groups that were evaluated separately were feed crops (hay, forage and feed grains), food crops (vegetables, fruits, food grains, and others) and livestock products (meat animals, milk and poultry products). Table 2-5 shows the value of existing production, compared with projected values for the years 1980, 2000, and 2020.

**TABLE 2-5. Puget Sound Area—value of production by major product group 1963-2020[1] (in thousands of dollars)**

| | 1963 | 1966[2] | 1980 | 2000 | 2020 |
|---|---|---|---|---|---|
| Feed Crops | 9,205 | 9,000 | 7,244 | 4,462 | 1,650 |
| Food Crops | 21,123 | 23,480 | 33,006 | 45,609 | 60,315 |
| Livestock | 97,310 | 102,000 | 124,629 | 163,353 | 211,862 |

[1] Agricultural economy of the Puget Sound and Adjacent Waters Area, Projections 1980, 2000 and 2020, Exhibit A, Appendix IV, Economic Environment.

[2] Interpolated to determine existing current base.

These projections indicate that feed crops will be expected to decline at an annual average rate of about 2.8 percent between 1966 and 2020. Food crops are expected to increase at a rate of about 1.9 percent per year and livestock at about 1.5 percent annually.

In projecting the growth in the value of agricultural production in each of the flood plains the following factors were considered: acres of productive agricultural land in the flood plain, present and future crop patterns, idle or fallow lands to be brought into production, agricultural land lost to urban and other types of encroachment, and flood plain management practices. Although feed crop production is expected to decline for the Puget Sound Area as a whole, conversion from natural to seeded pasture will result in increased output and value of feed crops in some flood plain areas. Overall productivity increases in each flood plain are expected to average between one and two percent annually. The resulting increase in production levels between specified time periods is shown in Table 2-6.

**TABLE 2-6. Agriculture—percentage increase in productivity levels for specified periods by basins**

| Basin | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Nooksack-Sumas | 25 | 28 | 25 |
| Skagit-Samish | 19 | 27 | 25 |
| Stillaguamish | 29 | 31 | 30 |
| Snohomish | 25 | 28 | 25 |
| Cedar-Green | 26 | 24 | 26 |
| Puyallup | 29 | 31 | 31 |
| Nisqually-Deschutes | 20 | 29 | 29 |
| West Sound | 18 | 26 | 26 |
| Elwha-Dungeness | 18 | 26 | 26 |

## Non-Agricultural

In estimating the level of future non-agricultural damages, growth in damageable items in the following seven categories were considered: buildings and equipment, transportation facilities, utilities, flood protective works, parks and fish hatcheries, flood relief expenditures, and employee and business losses. Estimates of residential damage, which is a large part of the buildings and equipment component, considered future population growth, projected per capita income and the pattern of consumption expenditures to identify the projected trend in expenditures on real and personal property items subject to flood damage. For commercial buildings and equipment, the rate of growth was based upon projected total consumer purchasing power within the service area of the commercial developments. Projected industrial output and projected acreage requirements for industrial use in each flood plain provided the basis for estimating growth of industrial buildings and equipment.

The growth in transportation facilities was based upon local and regional population rates of growth. Future flood damage to public utilities was expected to increase at a rate similar to trends in electric power, municipal and industrial water and gas consumption, and telephone installations. Additional flood protective works will depend on future land use trends and building permits issued in flood prone areas. The future need for increased park facilities and fish hatcheries was based on local and regional population growth. Flood relief expenditures are expected to follow retail price indexes and population growth trends. The growth in employee and business losses was based on employment and wage trends and volume of retail and wholesale inventories and sales.

**TABLE 2-7. Non-agricultural developments—composite average annual growth rate, by basin**

| Basin | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| | % | % | % |
| Nooksack-Sumas | 3.50 | 3.50 | 3.50 |
| Skagit-Samish | 3.50 | 3.50 | 3.50 |
| Stillaguamish | 3.50 | 3.75 | 3.75 |
| Snohomish | 3.50 | 3.75 | 3.75 |
| Cedar-Green | 3.75 | 4.00 | 4.00 |
| Puyallup | 3.25 | 3.75 | 3.75 |
| Nisqually-Deschutes | 1.75 | 2.50 | 2.50 |
| West Sound | 2.25 | 2.25 | 2.25 |
| Elwha | 1.75 | 1.75 | 3.00 |
| Dungeness | 2.00 | 2.00 | 2.25 |

The composite rate of growth for non-agricultural developments and damages in the flood plains of the various basins, ranging from 1.75 to 4.00 percent annually, are shown in Table 2-7.

The percentage increase in non-agricultural developments that would occur during specified time periods in each basin, based upon the annual growth rates as derived above, are shown in Table 2-8.

**TABLE 2-8. Non-agricultural developments—percentage increase in developments for specified periods by basins**

| Basin | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Nooksack-Sumas | 60 | 100 | 100 |
| Skagit-Samish | 60 | 100 | 100 |
| Stillaguamish | 60 | 110 | 110 |
| Snohomish | 60 | 110 | 110 |
| Cedar-Green | 75 | 120 | 120 |
| Puyallup | 55 | 110 | 110 |
| Nisqually-Deschutes | 20 | 60 | 60 |
| West Sound | 35 | 55 | 55 |
| Elwha | 25 | 40 | 85 |
| Dungeness | 45 | 50 | 55 |

## ANNUAL DAMAGES AT FUTURE DEVELOPMENT LEVELS

Annual damages representative of existing conditions are based on 1966 developments. Based on the projected increases in the agricultural and non-agricultural components in each basin, estimates were made of total future damages that would be sustained at development levels prevailing in future years. Annual damages at 1966 development levels and at 1980, 2000, and 2020 development levels are shown in Table 2-9.

**TABLE 2-9. Existing and future annual damages (in thousands of dollars)**

| Basin | Under Development Levels of 1966 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Nooksack-Sumas | 853 | 1,210 | 1,970 | 3,350 |
| Skagit-Samish | 3,020 | 4,340 | 7,060 | 12,030 |
| Stillaguamish | 256 | 380 | 690 | 1,310 |
| Snohomish | 2,310 | 3,520 | 6,370 | 13,100 |
| Cedar-Green | 447 | 780 | 1,700 | 3,740 |
| Puyallup | 100 | 151 | 301 | 602 |
| Nisqually-Deschutes | 57 | 69 | 110 | 160 |
| West Sound | 51 | 68 | 100 | 158 |
| Elwha | 4 | 6 | 9 | 14 |
| Dungeness | 24 | 32 | 45 | 66 |
| Total | $7,122 | $10,556 | $18,355 | $34,532 |

Annual damages of $7,122,000 under 1966 conditions of development will increase to $10,550,000 under 1980 conditions of development, to $18,360,000 under 2000 conditions of development and to $34,530,000 under 2020 conditions of development, if no further flood protection is provided. The framework flood control plan for alleviation of damages encompasses a long-range development sequence with some projects proposed by the year 1980, others by the years 2000 and 2020. There are, therefore, no future conditions to which an estimate of equivalent annual damages without further protection is pertinent. However, an economic analysis of the initial components of the plan, to be constructed by 1980, with benefits and costs evaluated over a common economic life, is presented in a later section of this report.

# MEANS TO SATISFY NEEDS

## FLOOD CONTROL OBJECTIVE

The flood control objective for the Puget Sound Area is to provide an overall program which will permit the use and development of flood plain lands for the optimum benefit of the region's population and its economic activities. Accomplishment of this objective requires structural measures to reduce flood damages to existing and future developments, nonstructural measures to control and minimize damages in areas where the need for or potential use of the flood plain lands do not warrant structural measures of protection, and selected open space lands and natural streams need to be preserved for optimum contribution to a desirable environmental quality.

Farm lands in several of the basin flood plains are being rapidly converted to residential and commercial use as a result of the expansion of adjacent metropolitan areas. Because of the decrease in available farm land, protection of remaining agricultural lands is essential in order that production capacity can be expanded to meet local market needs.

With the increasing demand for recreation areas, portions of the flood plain lands in most river basins should be set aside for parks, golf courses, and other general recreation uses such as swimming beaches, public boat launching ramps, and scenic drives. Minimum flood protection, to permit maintenance of adequate landscaping and service facilities, is required for recreation lands.

In setting up a flood management program for each basin, consideration was given to the optimum combination of all available structural and nonstructural means of effecting damage reductions. Structural considerations included storage reservoirs, levees, channel improvements, channel diversions, and watershed treatment. Nonstructural measures considered were flood plain zoning and regulations to restrict developments, flood proofing, flood fighting and flood warning systems, and the possibilities of flood plain evacuation.

## OBJECTIVES OF STRUCTURAL MEASURES

Standards of protection established for proposed flood control projects varied according to the type and intensity of existing and anticipated developments. The objective for urban and highly industrialized areas has been to provide at least a 100-year level of protection, with consideration wherever possible of standard project flood protection. The standard for agricultural lands has been to provide at least a 25-year level of protection and for recreation areas and facilities a 10-15 year level of protection.

Existing uses of the flood plain were determined and projections were made of future land needs for industrial, urban, agricultural and recreational uses, by flood plain areas. The resulting level of protection that should be provided by structural measures to the year 2020 is shown in Table 2-10.

**TABLE 2-10. Objectives of structural measures**

| | Levels of Protection[1] | | | |
|---|---|---|---|---|
| Flood Plain Designation | 100 Year | 50 Year | 25 Year | Less Than 25 Years |
| Nooksack River—49,000 acres | | | | |
| 6,200 acres along right bank below Ferndale | | | X | |
| 5,000 acres along left bank opposite Lynden | | | X | |
| 5,000 acres along right bank Lynden to Everson | | | X | |
| 3,000 acres in Sumas flood plain which floods from overflow of Nooksack River | | | X | |
| Portions of communities of Acme, Clipper, Deming, Everson, Nooksack, Sumas, Lynden, Ferndale, and Marietta (2000 acres) | X | | | |
| 4,000 acres along right and left banks of the South Fork—river mile 0-12 | | | X | |
| 23,800 acres (includes area required for floodway) | | | | X |
| Skagit River—90,000 acres | | | | |
| 66,000 acres of delta area located west of the town of Sedro Woolley | | X | | |
| 21,000 acres of river bottom land east and upstream of the town of Sedro Woolley | | | X | |
| Urban areas of Sedro Woolley, Burlington, Mount Vernon, LaConner, Edison, Hamilton Lyman (3000 acres) | X | | | |
| Stillaguamish River—12,600 acres | | | | |
| 300 acres in city of Stanwood | X | | | |
| 7,000 acres in the vicinity of Stanwood (North of River) Downstream of Silvana | | | X | |
| 4,400 acres of agriculturally productive land Silvana to Arlington | | | X | |
| 900 acres upstream of Arlington | | | | X |

TABLE 2-10. Objectives of structural measures (Continued)

| Flood Plain Designation | Levels of Protection[1] 100 Year | 50 Year | 25 Year | Less Than 25 Years |
|---|---|---|---|---|
| Snohomish River—25,000 acres | | | | |
| 7,300 acres in Snohomish River Delta | X | | | |
| 1,000 acres in the vicinity of the town of Snohomish | X | | | |
| 12,200 acres of agricultural land | | | X | |
| 1,000 acres along right bank for recreation use | | | | X |
| 3,500 acres (includes area required for floodway) | | | | X |
| Snoqualmie River—23,000 acres | | | | |
| 4,000 acres upstream from Snoqualmie Falls | X | | | |
| 600 acres in vicinity of Carnation | X | | | |
| 18,400 acres downstream from Snoqualmie Falls for improved agricultural lands | | | X | |
| Skykomish River—11,000 acres | | | | |
| 2,500 acres in vicinities of Monroe, Sultan and Goldbar | X | | | |
| 8,500 acres from Gold Bar to the confluence with the Snoqualmie River | | | X | |
| Cedar River—800 acres | | | | |
| 800 acre flood plain from Maple Valley to River's Mouth | X | | | |
| Sammamish River—3,600 acres | | | | |
| 3,600 acres located between Lake Sammamish and Lake Washington | X | | | |
| Green River—22,700 acres | | | | |
| 22,700 acre flood plain below Auburn | X | | | |
| Puyallup River—18,500 acres | | | | |
| 6,150 acres below Sumner | X | | | |
| 10,500 acres located from Sumner to about two miles above Orting | X | | | |
| 1,000 acres near the town of South Prairie | | | X | |
| 850 acres along the White River | X | | | |
| Nisqually River—9,000 acres | | | | |
| 7,800 acres below Alder Reservoir | | | X | |
| 1,000 acres above Alder Reservoir | | | | X |
| 200 acres near town of McKenna | X | | | |
| Deschutes River—2,700 acres | | | | |
| Residential and industrial (1000 acres) in town of Tumwater and city of Olympia | X | | | |
| Agricultural lands upstream of Tumwater (1700 acres) | | | X | |
| Skokomish River—4,600 acres | | | X | |
| Hamma Hamma River—66 acres | | | | X |
| Duckabush River—70 acres | | X | | |
| Dosewallips River—250 acres | | X | | |
| Big Quilcene River—171 acres | X | | | |
| Little Quilcene River—93 acres | | | X | |
| Dungeness River—2,900 acres | | | X | |
| Elwha River—750 acres | | | X | |

[1] For floods that can be expected to occur on an average of once in the period designated.

## SOLUTIONS TO FLOOD CONTROL NEEDS

The flood control plan for the Puget Sound Area combines structural measures for control of flood waters and nonstructural measures for controlling the use of the land. Flood plain regulations are utilized to establish and protect a required minimum channel for passage of flood flows and to control land use and development to reasonable limits for those areas with less than a 100-year level of flood protection. Effectiveness of such measures has been included in evaluation of the basin plan accomplishments. The effectiveness of zoning regulations and controls requires proper implementation, administration and enforcement by State and local governments. Changes are needed in the existing State legislation, Chapter 86.16 RCW (Revised Code of Washington), an act relating to flood control, to permit effective regulation of the flood plain. These needs are summarized below and are stated in greater detail in Appendix II, Political and Legislative Environment. Specifically, a revision to the code should:

a. Include State-wide coverage of all watercourses; rivers, creeks, lakes, and coastal areas.

b. Define explicitly the minimum requirements of flood plain regulations to be adopted by local governments and establish time limitation for this accomplishment. The prescribed regulations should be included in sub-division regulations, zoning ordinances and building codes.

c. Provide for retention of authority at the state level to invoke proper land use regulations in the absence of appropriate local action.

d. Provide for the enforcement of adopted regulations, declare certain acts unlawful and specify penalties to be applied.

Portions of the Skagit and Sauk Rivers and tributaries are designated for study, under Public Law 90-542, to determine their suitability for inclusion in the National Wild and Scenic Rivers System. In addition to the Skagit and Sauk, there are other rivers or river segments within the region that should be considered for preservation in their natural state for recreation use. A list of these rivers is contained in Appendix X, Recreation.

Most of the individual basin flood control plans involve various combinations of structural measures for controlling flood waters in conjunction with nonstructural measures for minimizing future flood damages. Features of the plan shown in Table 2-11, are evaluated for the single purpose of flood control.

**TABLE 2-11. Proposed flood control plan**

| Flood Control Feature | Effective Flood Control Storage Acre-Feet | River Mile | Height of Dam Feet | Channel Design Capacity (cfs) | Sequence of Development To 1980 | To 2000 | To 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|---|---|---|---|
| Nooksack–Sumas Basins | | | | | | | | |
| Edfro Dam Storage Project | 63,000 | 15.2 | 170 | -- | X | | | $ 27,200,000 |
| Levee–Rt. bank below Ferndale–6 mi. | -- | -- | -- | 47,000 | X | | | 2,500,000 |
| Levee–Rt. bank Lynden to above Everson–7 miles | -- | -- | -- | 47,000 | | X | | 3,500,000 |
| North Fork Dam Storage Project | 21,000 | 65 | 200 | -- | | X | | 21,400,000 |
| Levee construction on left bank opposite Lynden–10 miles | -- | -- | -- | 25,000 | | X | | 5,000,000 |
| Levee to protect the town of Sumas | -- | -- | -- | -- | | X | | 1,500,000 |
| Flood Plain Management | -- | -- | -- | -- | X | X | X | 7,000 |
| Skagit-Samish Basins | | | | | | | | |
| Ross Dam Storage on Skagit River | 120,000 | 102.7 | 540 | -- | X | | | Existing |
| Upper Baker Dam Storage on Baker River | 100,000 | 9 | 330 | -- | X | | | Existing[1] |
| Avon Bypass Channel–Skagit River Delta | -- | -- | -- | 60,000 | X | | | 28,900,000 |
| Levee and channel improvements from the Burlington-Mount Vernon area downstream to the rivers mouth | -- | -- | -- | 120,000 | X | | | 7,000,000 |
| Levee construction–Nookachamps Creek Area–5.5 miles | -- | -- | -- | 135,000 | X | | | 2,500,000 |

[1] Project operation would be changed to provide for flood control storage. Reimbursement for power loss would be required.

**TABLE 2-11. Proposed flood control plan (Continued)**

| Flood Control Feature | Effective Flood Control Storage Acre-Feet | River Mile | Height of Dam Feet | Channel Design Capacity (cfs) | Sequence of Development To 1980 | To 2000 | To 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|---|---|---|---|
| Skagit-Samish Basins (Continued) | | | | | | | | |
| Lower Sauk flood control storage | 134,000 | 5 | 170 | -- | | X | | 61,200,000 |
| Levee construction to protect the town of Hamilton | -- | -- | -- | 180,000 | | X | | 2,800,000 |
| Levee construction to protect the town of Sedro Woolley | -- | -- | -- | 180,000 | | X | | 3,000,000 |
| Flood Plain Management | -- | -- | -- | -- | X | X | X | 2,500 |
| Stillaguamish Basin | | | | | | | | |
| Levees and channel improvements to protect Stanwood and the flood plain upstream to Silvana | -- | -- | -- | 93,000 | X | | | $ 7,700,000 |
| Levee construction—Silvana upstream to Arlington | -- | -- | -- | 73,000 | | X | | 3,700,000 |
| Storage at Robe site on South Fork | 70,000 | 24 | 240 | -- | | | X | 21,200,000 |
| Storage at Oso site on North Fork | 80,000 | 2.1 | 200 | -- | | | X | 25,100,000 |
| Flood Plain Management | -- | -- | -- | -- | X | X | X | 2,000 |
| Snohomish Basin | | | | | | | | |
| North Fork Snoqualmie Storage Project | 50,000 | 11.9 | 300 | -- | X | | | $ 29,200,000 |
| Middle Fork Snoqualmie Storage Project | 120,000 | 10.0 | 190 | -- | X | | | 40,700,000 |
| Sultan River Storage Project | 100,000 | 14.0 | 265 | -- | X | | | 13,400,000 |
| Estuary channel and levees—mouth of Snohomish River to River Mile 3.0 | -- | -- | -- | 113,000 | X | | | 25,650,000 |
| Set back existing levee from River Mile 10 to River Mile 18.5 | -- | -- | -- | 90,000 | X | | | 6,300,000 |
| North Fork Skykomish Storage Project | 140,000 | 6.2 | 340 | -- | | X | | 129,400,000 |
| Estuary channel and levees River Mile 3.0 to 6.3 | -- | -- | -- | 113,000 | | X | | 32,470,000 |
| Storage on Miller River | 45,000 | 0.6 | 230 | -- | | | X | 47,900,000 |
| Storage on Beckler River | 70,000 | 1.3 | 220 | -- | | | X | 43,900,000 |
| Storage on Pilchuck River | 15,000 | 22.0 | 200 | -- | | | X | 15,700,000 |
| Storage on South Fork Tolt | 15,000 | 6.6 | Existing | -- | | | X | 2,000,000 |
| Estuary channel and levee River Mile 6.3 to 10.0 | -- | -- | -- | 113,000 | | X | | 36,255,000 |
| Levee construction—Carnation—2 miles | -- | -- | -- | 20,000 | | X | | 200,000 |
| Levee construction—Gold Bar—3 miles | -- | -- | -- | 80,000 | | X | | 1,500,000 |
| Levee construction—Skykomish—1 mile | -- | -- | -- | 15,000 | | X | | 200,000 |
| Levee construction—Sultan—3 miles | -- | -- | -- | 80,000 | | X | | 1,500,000 |
| Levee construction—Monroe—3 miles | -- | -- | -- | 85,000 | | X | | 1,500,000 |
| Flood Plain Management | -- | -- | -- | -- | X | X | X | 5,000 |
| Cedar-Green Basins | | | | | | | | |
| Flood control storage on Cedar River at Chester Morse Lake | 50,000 | 83 | 80 | -- | X | | | $ 5,610,000 |
| Flood control storage at Howard A. Hanson Reservoir on the Green River | 106,000 | 64 | 235 | -- | X | | | Existing |
| Levee and channel improvements on Green River from Auburn to Rivers Mouth | -- | -- | -- | 12,000 | X | | | 12,000,000 |
| Storage on Taylor Creek on Cedar River | 10,000 | 5 | 100 | -- | | | X | 10,200,000 |
| Storage in Lake Sammamish on Sammamish River | 6,000 | -- | -- | -- | | | X | 1,000,000 |

**TABLE 2-11. Proposed flood control plan (Continued)**

| Flood Control Feature | Effective Flood Control Storage Acre-Feet | River Mile | Height of Dam Feet | Channel Design Capacity (cfs) | Sequence of Devleopment To 1980 | To 2000 | To 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|---|---|---|---|
| Cedar-Green Basins (Continued) | | | | | | | | |
| Levee and channel improvements Lake Sammamish to Lake Washington | -- | -- | -- | 3,000 | | | X | 2,000,000 |
| Flood Plain Management on Cedar-Green and Sammamish River flood plains | -- | -- | -- | -- | X | X | X | 81,000 |
| Puyallup Basin | | | | | | | | |
| Channel and levee construction on Puyallup and Carbon Rivers at Orting | -- | -- | -- | 19,000 | | X | | $ 1,600,000 |
| Flood control storage at Mud Mountain Dam and Reservoir on White River | 106,000 | 28 | -- | -- | X | | | Existing |
| Storage on Puyallup River at Orting site | 24,000 | 10 | -- | -- | | X | | 26,500,000 |
| Levee construction on South Prairie Creek | -- | -- | -- | -- | | X | | 1,000,000 |
| Storage on South Prairie Creek | 8,500 | 10 | -- | -- | | | X | 15,300,000 |
| Flood Plain Management | -- | -- | -- | -- | X | X | X | 160,000 |
| Nisqually-Deschutes Basins | | | | | | | | |
| Alder Reservoir Flood Control Storage—Nisqually River | 55,000 | 35 | 330 | -- | | X | | Existing[1] |
| Levee and channelization for Port development at Nisqually River delta area | -- | -- | -- | -- | | | X | $ 3,000,000 |
| Storage at Shellrock Ridge site on Deschutes River | 15,000 | -- | 115 | -- | | | X | 3,500,000 |
| Flood Plain Management | -- | -- | -- | -- | X | X | X | 82,000 |
| West Sound Basins | | | | | | | | |
| Levee construction to protect Dosewallips State Park near the mouth of the Dosewallips River | -- | -- | -- | -- | X | | | $ 150,000 |
| Levee on the right river bank Big Quilcene River | -- | -- | -- | -- | | X | | 240,000 |
| Levees for Hamma Hamma River flood plain | -- | -- | -- | -- | | | X | 180,000 |
| Levees to protect Duckabush flood plain | -- | -- | -- | -- | | | X | 220,000 |
| Levee on left river bank of Dosewallips River from River Mile 0 to River Mile 5 | -- | -- | -- | -- | | | X | 500,000 |
| Levee on left river bank Big Quilcene River | -- | -- | -- | -- | | | X | 180,000 |
| Levee on left and right banks Little Quilcene River | -- | -- | -- | -- | | | X | 220,000 |
| Flood Plain Management | -- | -- | -- | -- | X | X | X | 81,000 |
| Elwha-Dungeness Basins | | | | | | | | |
| Levees on left bank River Mile 0 to 8 (Dungeness River) | -- | -- | -- | -- | | | | $ 2,500,000 |
| Levees on right bank River Mile 0 to 1.5 (Elwha River) | -- | -- | -- | -- | | | | 250,000 |
| Flood Plain Management | -- | -- | -- | -- | X | X | X | 33,000 |
| | | | Total Cost of Plan | | | | | $738,578,500 |

[1] Project operation would be changed to provide for flood control storage. Reimbursement for power loss would be required.

Expansion from single-purpose to multi-purpose projects is considered under basin plan formulation in Appendix XV. Total cost of the proposed flood control projects to the year 2020 is estimated to be approximately $738,578,500. Each of the basin flood control plans is detailed under the individual basins.

All stimates of costs contained in this appendix must be considered preliminary, subject to verification by more detailed studies. These estimates are, however, of sufficient accuracy for use in developing the flood control features of multi-purpose projects for river basin plans. Further refinements will be required in studies leading to project authorization.

The basin flood control plans for the 1980 level of development provide for 603,000 acre-feet of flood control storage, construction of 85 miles of levee, and improvement of 35 miles of river channel. Approximately 211,000 acres require flood plain management. By the year 2000 an additional 374,000 acre-feet of storage would be provided, 42 miles of additional levees and 12 miles of channel improvements would be constructed, and flood plain management would be required for 126,800 acres of flood plain land. By the year 2020, flood protection for the area would require an additional 334,000 acre-feet of storage and 40 miles of levee construction.

## ACCOMPLISHMENTS OF THE 1980 PLAN

Implementation of the flood control plan will reduce present and future flood damages appreciably. Urban and industrial utilization of the flood plain will be possible on selected lands. Increased agricultural production would be possible on the majority of the land remaining in agricultural use and the preservation of open space could be maintained by managing the downstream flood plains within the limitations of flood protection provided. Recreation facilities near the flood control storage reservoirs and on flood plain lands provided with a 10-15 year level of protection could serve the increasing demands of a growing population.

An analysis of the benefits and costs of the 1980 plan is shown in Table 2-12, by basins, for flood control only. Cost estimates are based on field reconnaissance, topographic maps, and office studies. Detailed data from previous studies were utilized where available. Annual costs include interest and amortization of the total investment (including interest during construction), average annual costs of operation and maintenance and equivalent average annual cost of major replacement costs. An interest rate of 4-5/8 percent was used to compute interest during construction and the annual costs of interest and amortization. An economic life of 100 years was used for storage projects and an economic life of 50 years was used for levee construction.

**TABLE 2-12. Costs and benefits of structural measures for 1980 portion of proposed flood control plan[1]**

| Basin | Estimated Development Costs (Based on 1968 Prices) | Estimated Annual Costs (Based on 1968 Prices) | Estimated Average Annual Flood Control Benefits (1966 Prices) |
|---|---|---|---|
| Nooksack | $ 29,700,000 | $ 1,672,500 | $ 1,315,000 |
| Skagit | 38,400,000 | 2,137,600 | 3,450,000 |
| Stillaguamish | 7,700,000 | 454,000 | 500,000 |
| Snohomish | 115,250,000 | 6,305,000 | 7,510,000 |
| Cedar | 5,610,000 | 312,000 | 298,000 |
| Green | 12,000,000 | 650,000 | 723,000 |
| Puyallup | -- | -- | -- |
| Nisqually-Deschutes | -- | -- | -- |
| West Sound | 150,000 | 11,000 | 11,500 |
| Elwha-Dungeness | -- | -- | -- |
| Total for Puget Sound Area | $208,810,000 | $11,542,100 | $13,807,500 |

[1] These are costs and benefits for single-purpose flood control. The inclusion of multiple purposes in storage projects will increase total benefits and reduce costs due to joint use of storage.

Benefits are the average annual values over the economic life of the projects. These were derived utilizing the growth rate in developments and damages to 2020, as previously explained, and converting future benefits to an equivalent annual amount at a discount rate of 4-5/8 percent. The growth in damages beyond the year 2020 was assumed to be at one-half the projected rate up to that time.

The flood control benefits consist of two components: flood damage prevention benefits and land enhancement benefits. The flood damage prevention benefits are the reduction in damages to land and property, the reduction in business losses and reduction in flood fighting and emergency costs. Land

enhancement benefits are the benefits accruing from increased or higher utilization of land resulting directly from the elimination of flood hazards.

Total costs for flood control structural measures proposed for development in the period up to 1980 are $208,810,000, with estimated annual costs of $11,302,000. Average annual benefits are estimated at $13,807,500. In addition to the evaluated benefits, important intangible benefits including prevention of loss of life and human suffering and reduction of health hazards, would result from the proposed protection plan.

## ACCOMPLISHMENTS OF THE LONG RANGE PLAN

Accomplishments of the overall Puget Sound Area flood control plan are shown in Table 2-13. The level of protection evaluated for each time period is not identical to that proposed in Table 2-10, Objectives to Structural Measures, because of economic considerations and because the flood control features selected to provide the desired protection may result in a higher or lower level of protection to portions of the flood plain. The sequence of development also affects the ultimate level of protection provided for segments of the flood plain.

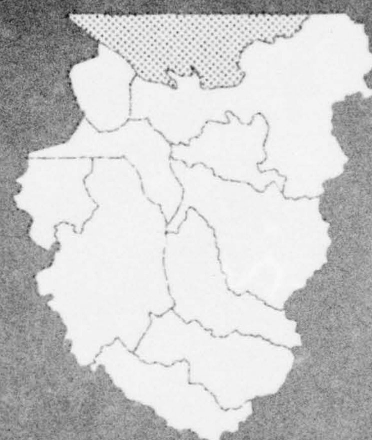
Without protection and without any flood plain regulation, annual damages estimated at $7,122,000 at 1966 levels of development could increase to $10,550,000 based on 1980 levels of development, $18,360,000 at 2000 development levels, and $34,530,000 at 2020 development levels. Flood plain regulation would not be effective in reducing damages to certain types of flood plain use, such as agricultural, transportation and recreation. It could, however, reduce damages to buildings and equipment that would otherwise be sustained in developed areas and zoning restrictions could further reduce potential damages by limitation on certain types of development. The extent to which damages would be reduced by these measures is estimated as shown in Table 2-13, at $770,000 annually, based on 1980 conditions, increasing to $6,942,000 based on 2020 conditions. Structural measures are, therefore, required to effect the substantial control and damage reduction needed throughout the area's flood plains.

**TABLE 2-13. Accomplishments of Puget Sound Area flood control plan—proposed projects and developments**

| | 1980 | 2000 | 2020 |
|---|---|---|---|
| Acreage Protected by Structural Measures | | | |
| 100 year protection | 61,000 | 145,200 | 165,300 |
| 50 year protection | 64,000 | 5,200 | 5,400 |
| 25 year protection | 21,300 | 39,700 | 37,900 |
| Less than 25 year protection | 125,700 | 81,900 | 63,400 |
| Flood Plain Management (acres) | 211,000 | 126,800 | 106,700 |
| Flood Damage Prevention (dollars) | | | |
| Projected average annual flood damages without additional protection | $10,550,000 | $18,360,000 | $34,530,000 |
| Reduction in future average annual flood damages due to flood plain management | 770,000 | 2,781,000 | 6,942,000 |
| Projected residual average annual flood damages with flood plain management | 9,780,000 | 15,579,000 | 27,588,000 |
| Reduction in future average annual flood damages with implementation of structural measures | 7,387,000 | 13,235,000 | 24,978,000 |
| Residual average annual flood damages | $ 2,393,000 | $ 2,344,000 | $ 2,610,000 |

The proposed plan would provide 100-year protection to 61,000 acres by 1980, to 145,000 acres by 2000 and to 165,000 acres by 2020. Annual damages based on anticipated 1980 developments would be reduced by $7,387,000 by projects included in the development plan up to that time. Damage reduction by these and the additional projects proposed by the year 2000 would total $13,235,000 based on developments forecast at that time. The complete plan, by the year 2020, would eliminate annual damages estimated to be $24,978,000 based on projected developments in the year 2020. Residual damages are estimated to be approximately 2½ million dollars at each of the projected periods. These become significantly smaller, relative to the economic development base, as the full sequence of projects are incorporated into the flood control plan.

# Nooksack-Sumas Basins



# NOOKSACK — SUMAS BASINS

## DESCRIPTION OF BASINS

### GENERAL

The Nooksack-Sumas Basins comprise about 1,256 square miles of land and inland water in northwestern Washington. Of these 807,990 acres, 760,000 are in Whatcom County. The basins, shown on Figure 3-1, are bounded on the north by the Fraser River Basin in British Columbia, on the east by the Skagit River Basin, on the south by the Skagit and Samish Basins, and on the west by the Strait of Georgia. Elevations vary from 10,750 feet at the summit of Mount Baker and 9,040 feet at the summit of Mount Shuksan to sea level. The eastern part of the basin is heavily timbered, mountainous terrain. West of Deming, the mountains drop sharply to the floor of a broad valley whose rolling surface varies from 400 feet to sea level.

Soils of the mountainous areas in the eastern part of the watershed consist of shallow mantles of loams, stony and rocky loams overlying bedrock of limestone, basalt, slate, shale, schist, gneiss, granite and quartzite. Soils of the western part of the basin were formed in cemented sandy glacial till, glacial clay till and outwash glacial sands and gravels. Their textures are loams, clay loams, sandy loams, gravelly sandy loams, sands and gravelly sands. The flood plains consist of sands and gravelly sands in the upper reaches and become progressively finer textured to fine sandy loams, silt loams, loams, clay loams and silty clay loams in the lower reaches. Peats and mucks occur in many small drainage basins.

Maritime air masses influence both precipitation and temperatures in the Nooksack-Sumas Basins, producing a mild, wet climate. Approximately 75 percent of the precipitation falls during the period October through March. The recorded mean annual precipitation varies from 109 inches on Mount Baker to 32 inches at Bellingham. The average monthly temperature at Bellingham ranges from 36 F in January to 61 F in August.

Natural resources include extensive forests, fertile farm land, large quantities of nonmetallic minerals, abundant supplies of fresh water, deep harbors, fish and wildlife, and a variety of recreational attractions.

### ECONOMY—PAST AND PRESENT

For practical purposes, statistics for Whatcom County are indicative of conditions in the Nooksack-Sumas Basins. The population of Whatcom County, divided almost equally between urban and rural, increased from 60,355 in 1940 and 70,317 in 1960 to 77,300 in 1967. This represents an annual growth rate of 1.2 percent since 1960 contrasted with 0.8 percent from 1940 to 1960. This acceleration is attributed to recent diversification in industry away from the traditional processing of timber, agricultural products, and seafood. Table 3-1 shows population for various years and areas including major communities. Figures are taken from U.S. Census Reports, except for 1967, which is derived from Washington State Census Board estimates.

Employment increased from 18,854 in 1940 to 27,891 in 1967. Greatest gains were made in construction and in trade and services. Moderate growth was made in food processing for which Lynden is a notable center. New industrial jobs became available in Ferndale at an aluminum plant and an oil refinery. The Pittsburgh Plate Glass Company plans expansion and modernization of their newly-acquired portland cement plant in Bellingham.

Traditional basic industries continue to provide employment. Three-quarters of Whatcom County is covered by commercial forests, 50 percent classified as saw-timber. Sawmill activity has declined, but pulp and paper production has expanded. Land in farms totals almost 177,000 acres. Agriculture, primarily dairying and the raising of poultry and beef, is carried on mainly in the lowlands. The most productive farm lands are in the Nooksack-Sumas valleys from Ferndale to Deming and Sumas. Recreational use of mountains, forests, lakes, streams, and salt-water beaches is increasing. Table 3-2 shows employment by year and category.

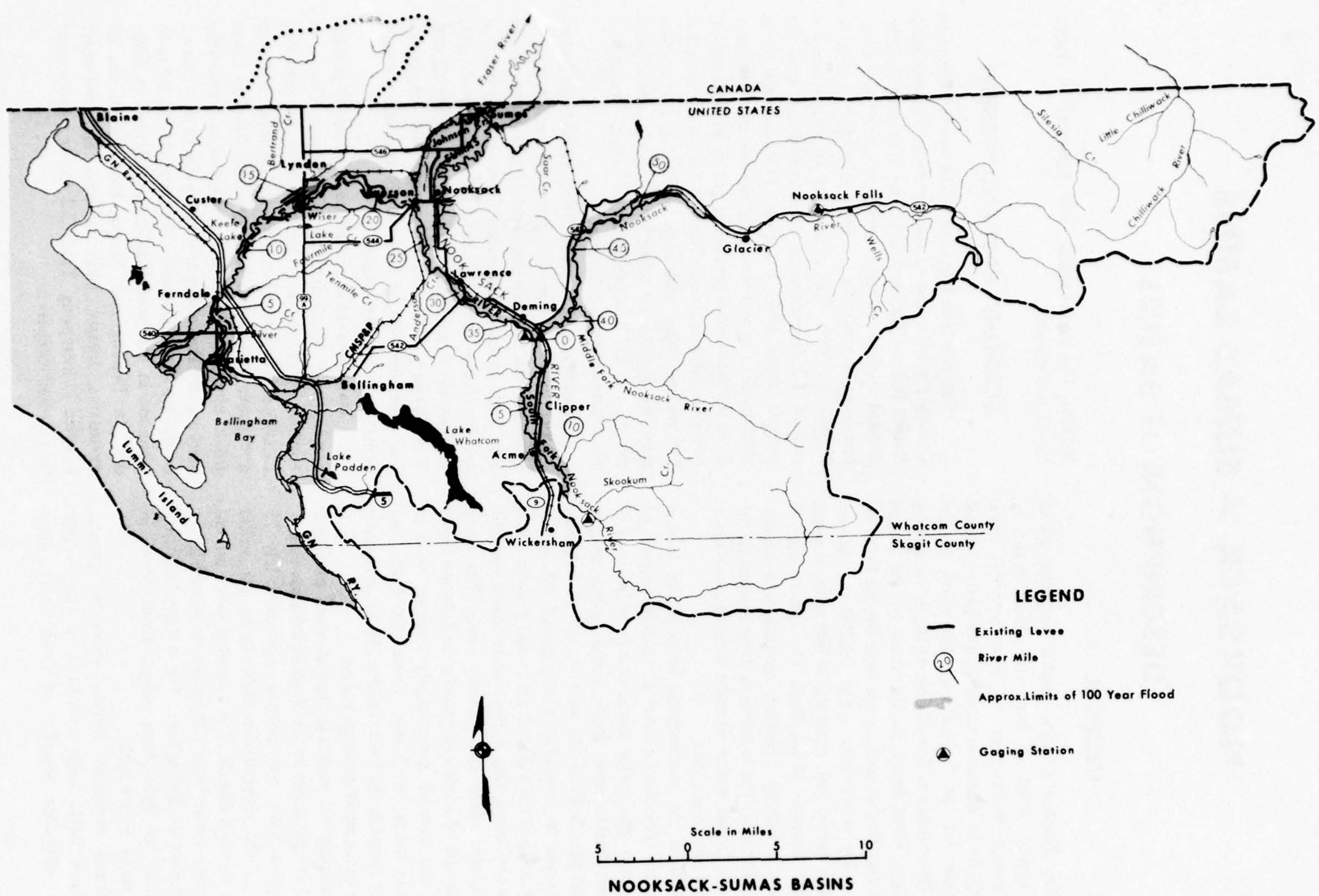
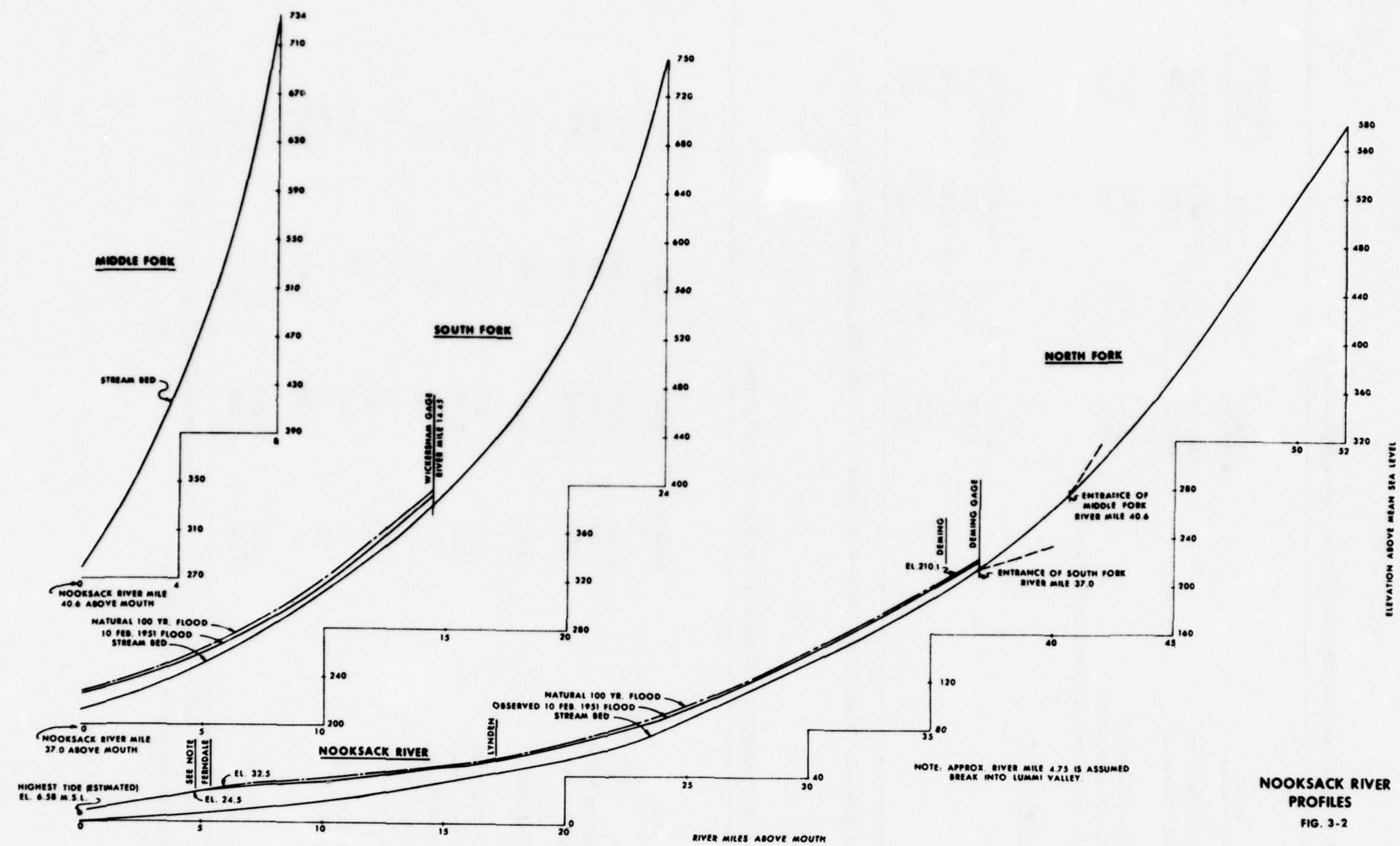



Figure 3–1 Flood Plain and Existing Protective Works




**NOOKSACK RIVER PROFILES**

FIG. 3-2

**TABLE 3-1. Population in Whatcom County—past and present**

| Area | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| United States (thousands) | 132,164 | 151,326 | 179,323 | 200,100 | 52 |
| Puget Sound (thousands) | 1,007 | 1,418 | 1,768 | 2,100 | 105 |
| North Division (thousands) | 107.3 | 124.3 | 144.2 | 156.2 | 46 |
| Whatcom County (thousands) | 60.4 | 66.7 | 70.3 | 77.3 | 28 |
| Nooksack Basin (approximately same as Whatcom County) | | | | | |
| Cities & Towns in Basin | | | | | |
| Bellingham | 29,314 | 34,112 | 34,688 | 36,500 | 24 |
| Lynden | 1,696 | 2,161 | 2,542 | 2,850 | 68 |
| Ferndale | 717 | 979 | 1,442 | 1,850 | 158 |
| Sumas | 650 | 658 | 629 | 674 | 4 |
| Everson | 292 | 345 | 431 | 625 | 114 |

Figures are from U.S. Census Report, Seattle Area Industrial Council, 1967, and Appendix IV, Economics.

**TABLE 3-2. Employment in Whatcom County—past and present**

| Industry | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| Agriculture | 4,277 | 4,513 | 3,680 | 2,750 | -36 |
| Forestry, Fishing, Mining | 660 | 747 | 324 | 609 | -1 |
| Contract Construction | 805 | 1,476 | 1,927 | 1,849 | 130 |
| Manufacturing Total | 3,652 | 4,163 | 4,566 | 6,596 | 81 |
| Food & Kindred Prods. | 662 | 800 | 1,017 | 1,470 | |
| Lumber & Wood Prods. | 2,084 | 2,115 | 1,165 | 1,050 | |
| Paper & Allied Prods. | 414 | NA | NA | NA | |
| Chem. & Allied Prods. | 11 | 21 | 24 | NA | |
| Fabricated Metal | 20 | 56 | 88 | 120 | |
| Machinery | 28 | 54 | 120 | NA | |
| Transportation Equip. | 53 | 108 | 301 | 400 | |
| Primary Metals | 45 | 33 | 24 | 40 | |
| All Other | 335 | 976 | 1,827 | 3,516 | |
| Non-Commodity Industry | 9,460 | 12,002 | 14,415 | 16,087 | 70 |
| Total Employment | 18,854 | 22,901 | 24,912 | 27,891 | 62 |

Figures are from U.S. Census reports except 1967 which is derived from Employment Security Act statistics. NA indicates information is not available for public release.

## PROJECTED ECONOMIC TRENDS

The economy of the Nooksack-Sumas Basins shares in the growth trends of the counties of Whatcom and Skagit which form the North Division of the Puget Sound Area. Both counties are oriented toward agriculture and food processing. Projections of economic growth for the North Division have been made for the years 1980, 2000, and 2020 in Appendix IV. Table 3-3 contains a forecast of population, employment and gross regional product for the North Division and projects population for Whatcom County as approximately equal to that of the Nooksack-Sumas Basins. Table 3-4 converts these forecasts into rates of growth and compares these rates to those projected for the United States.

**TABLE 3-3. Economic projections**

| North Division | 1963 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Population (thousands) | 151.0 | 185.5 | 249.9 | 341.5 |
| Employment (thousands) | 45.5 | 57.9 | 78.2 | 106.7 |
| Gross Regional Product (millions of 1963 dollars) | 369.0 | 848.0 | 1,800.0 | 3,977.0 |
| **Whatcom County (equivalent to Nooksack-Sumas Basins)** | | | | |
| Population (thousands) | 74.6 | 91.6 | 123.5 | 168.7 |

**TABLE 3-4. Average annual growth trends (percent)**

| | 1963 to 1980 | 1980 to 2000 | 2000 to 2020 | 1963 to 2020 |
|---|---|---|---|---|
| **United States** | | | | |
| Population | 1.3 | 1.3 | 1.3 | 1.3 |
| Employment | 1.6 | 1.4 | 1.3 | 1.5 |
| Gross National Product | 4.3 | 3.9 | 4.0 | 4.0 |
| **North Division** | | | | |
| Population | 1.2 | 1.5 | 1.6 | 1.4 |
| Employment | 1.4 | 1.5 | 1.5 | 1.5 |
| Gross Regional Product | 5.0 | 3.9 | 4.9 | 4.3 |
| **Whatcom County (equivalent to Nooksack-Sumas Basins)** | | | | |
| Population | 1.3 | 1.5 | 1.6 | 1.5 |

In the 57-year period following 1963, the projected average annual growth rate for the North Division is 1.4 percent for population, 1.5 percent for employment, and 4.3 percent for gross regional product. Because of industrial developments this is slightly greater than the pattern of expansion for the United States which is expected to realize rates of 1.3 percent,. 1.5 percent, and 4.0 percent for the same indicators and time period.

## LAND USE TRENDS

The Nooksack-Sumas flood plain is nearly entirely utilized for agriculture and is expected to remain in this use. Dairying is the predominant form of agriculture and most of the flood plain is in pasture or hay. There is a tendency for more of this acreage each year to be converted to the growing of vegetables such as peas, beans and corn under contract to local processers for canning or freezing. Annual profit from dairying and vegetable raising is about the same, but vegetables require a lesser investment in equipment and time. Probably the farming pattern of the future will be a mix of dairying operations for year-around income and vegetable raising for a lump sum cash receipt. Strawberries and raspberries do not do as well in the Nooksack Valley as in the Skagit because of the colder weather and more frequent freezing temperatures. However, delta lands downstream from Ferndale appear suitable for cole crops such as broccoli, brussel sprouts, cabbage and cauliflower. Another profitable use of farm lands, suited to the Nooksack Valley would be the raising of seed crops such as beets, spinach, and mustard. These crops are set out in the fall and would require a high degree of flood control. Currently the limited demand for seed is being met by production in the Skagit Valley. In summary, agriculture on the Nooksack-Sumas flood plain probably will continue under present practices well into the future, with some dairyland being converted to vegetable crops.

The largest city in the Nooksack-Sumas Basin, Bellingham, is remote from the flood plain. However, some building in areas subject to inundation continues to take place in the vicinity of Ferndale, Lynden, and Everson. All of these communities have high ground available, and the county is attempting by zoning to discourage expansion in the flood plain. Ferndale (population about 2,000) is the fastest growing community in the valley largely as a result of recent industrial development. The industrial sites are several miles from the town on high ground. The communities of Marietta, Nooksack and Sumas are small and comparatively static.

# NOOKSACK RIVER BASIN

## PRESENT STATUS

### Stream System

The Nooksack River Basin is about 50 miles long in an east-west direction, and has a maximum width in the United States of 30 miles. The river originates as the "North Fork" on the slopes of Mount Shuksan, meanders westerly 75 miles to Bellingham Bay, and drains an area of 826 square miles, including 49 square miles in Canada. As shown on Figure 3-1 the North and Middle Forks form the main stem which is joined by the South Fork above Deming. Prior to 1960, the Nooksack flowed into Lummi Bay along the course now followed by the Lummi River. A large debris dam blocked the river and diverted the flow to a creek flowing into Bellingham Bay. The creek offered an easier route to the sea, and the main channel has remained on this alinement. Table 3-5 shows the drainage areas of the Nooksack River and its principal tributaries. Stream profiles are shown on Figure 3-2.

**TABLE 3-5. Drainage area and average annual runoff**

| River | Drainage Area (sq. mi.) | Annual Average Runoff (ac. ft.) |
|---|---|---|
| North Fork | 293 | 1,130,000 |
| Middle Fork | 102 | 432,000 |
| South Fork | 183 | 782,000 |
| Main Stem and Lummi | 248 | 346,000 |
| Total | 826 | 2,690,000 |

### Flood Plain

Developments in the flood plain include portions of several cities and towns. Marietta, an unincorporated community of about 300 persons is on low ground in the delta area, on the left bank of the Marietta River, a distributary of the Nooksack. The town of Ferndale lies on the right bank of the Nooksack River, 5 miles above its mouth. Most of the residential area and much of the central business section is situated on the toe of the low broad hill which lies between the river and the coast. In the south part of town several commercial buildings are on land bordering the river at lower elevations. To the north there are several homes in the flood plain. The city of Lynden is located 17 miles upstream from the mouth of the Nooksack River on a bench just above the right edge of the flood plain. Although the city itself is on high ground, a small residential community has developed on the flood plain between the east end of the city and the river. A nearby concrete and asphalt materials plant is on the riverside, partially protected by a levee. At Everson, 23 miles upstream from the mouth of the Nooksack, there is a large cannery on the river's edge.

Interstate Highway 5, Bellingham to Vancouver, B.C., crosses the flood plain just upstream from Ferndale. More than one-half mile of its south approach is constructed on a low fill and has occasionally been inundated. An alternate route to the east is well above flood levels. Several other State and country roads are subject to flooding. Lines of the Great Northern, the Chicago, Milwaukee, St. Paul and Pacific, and the Northern Pacific Railroads are in the flood plain at elevations generally above flooding.

On the North and Middle Forks of the Nooksack the flood plain is generally not over one-half mile wide. On the South Fork there is a flood plain 1 to 1.5 miles in width in the lower 9 miles of the valley. From Deming to Everson the Nooksack flood plain is about a mile in width. Downstream from Everson the flood plain widens to 3 miles before reaching Lynden, narrows to 2 miles at Lynden and then gradually decreases in width to 1 mile near Ferndale. Below Ferndale the flood plain coincides with the triangular-shaped Nooksack-Lummi delta, each side of which is 5 miles long.

### History of Flooding

**Flood Characteristics**—High water on the Nooksack River coincides with the period of maximum precipitation in the fall or winter and with rising temperatures and melting of the accumulated snowpack in the mountains in spring or early summer. The North and Middle Forks have high flow periods which start with spring snowmelt and usually reach a maximum in June. Moderately high flows are sustained through September by glacier melt water. During the fall, warmer weather and heavy rainfall sometimes causes large flows. In the winter, precipitation usually falls in the form of snow in the higher elevations and remains until spring or early summer. After the first of January, these tributaries have comparatively low streamflows. The runoff pattern

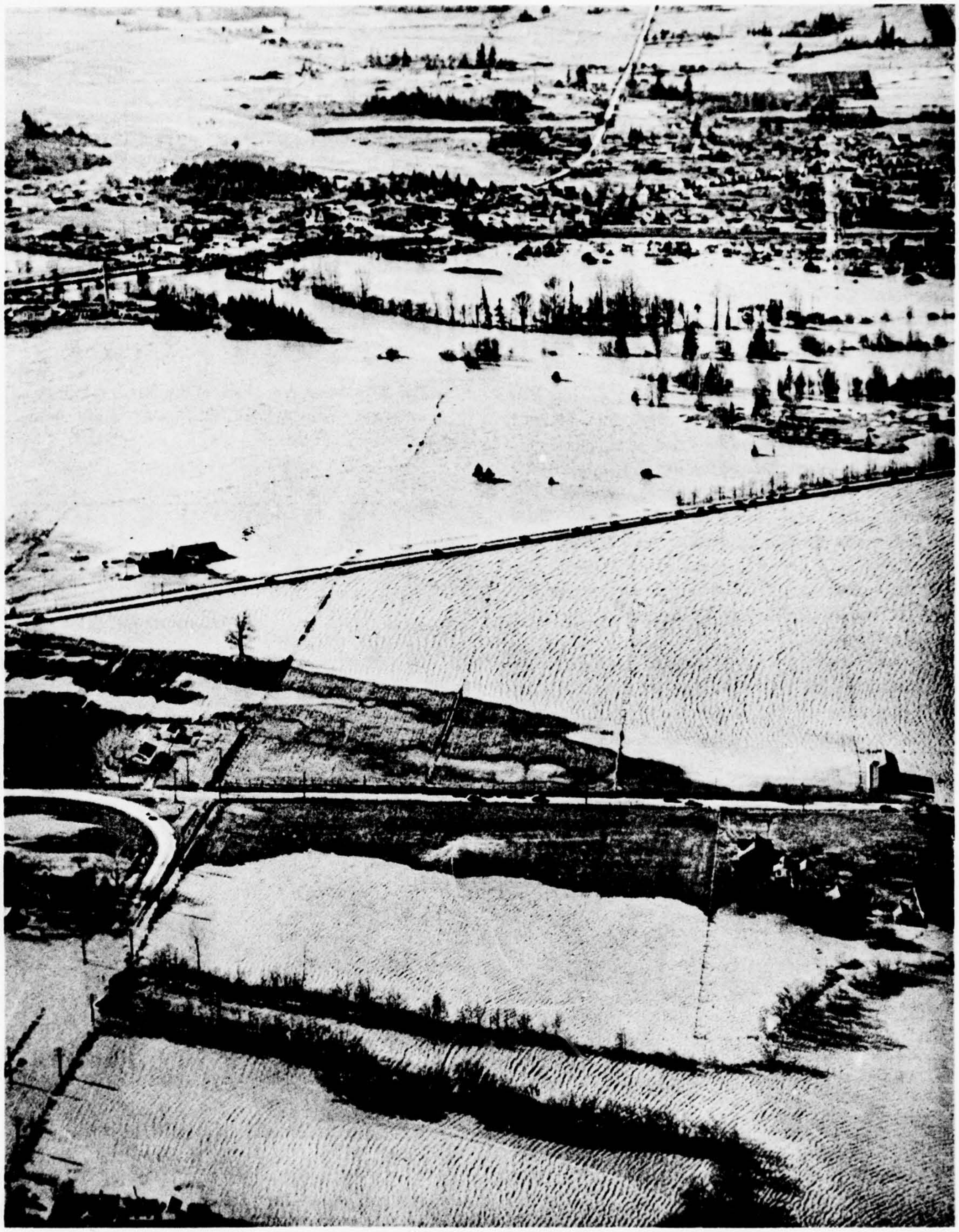


PHOTO 3-1. 1951 Flood at Ferndale.

for the North Fork is shown in Figure 3-3 and is also typical of the Middle Fork.

The flow of the South Fork rises with spring snowmelt, generally through June. The stream is not fed by glaciers, and drops to a low discharge in August. Largest runoff occurs from November through February as a result of heavy precipitation. The runoff pattern is shown in Figure 3-4.

Streamflow recorded at the Deming gage is typical of the main river. During May and June, as shown in Figure 3-5, the flow averages about 5,000 cfs. The flows decrease to about 1,800 cfs in September and begins to increase in October. Peak floodflows during the winter may be about 10 times greater than the average flow. The flow at Lynden is about 7 percent more than at Deming, and the flow at Marietta approximately 8 percent more than at Lynden. Figure 3-6 shows daily discharges at Deming.

**Floods**–High flows have been recorded on the Nooksack River intermittently since 1910 and continuously since 1933 at various gaging stations. About 19,000 cfs at Deming represents zero damage flow. Since 1932, the river has exceeded zero damage flow 34 times. Discharges greater than zero damage flow for the Nooksack River at Deming and Lynden are given in Table 3-6.

The major floods of record since 1933 and estimated 50 and 100-year flows are shown in Table 3-7 with their average recurrence intervals and estimated damages at 1966 prices and conditions.

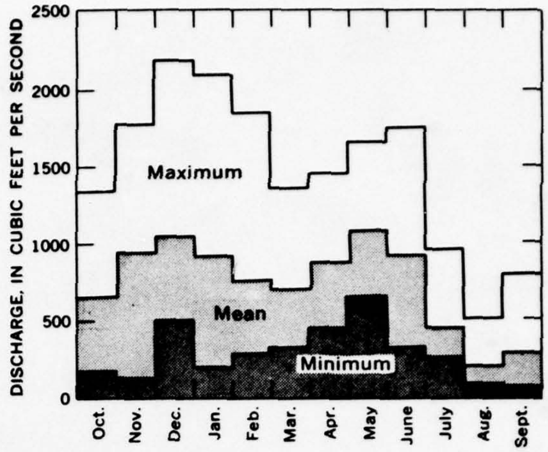



FIGURE 3-4. Maximum, mean and minimum monthly discharges, South Fork Nooksack River near Wickersham, 1931-60.

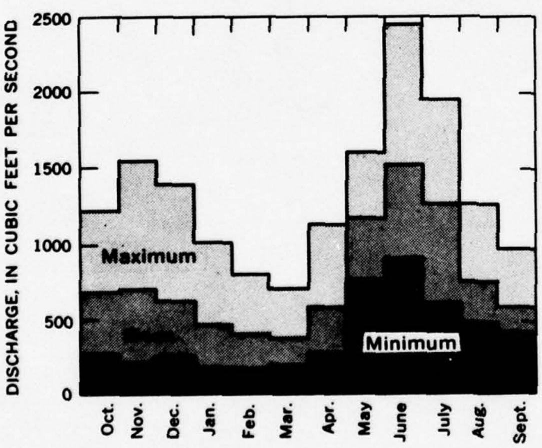



FIGURE 3-3. Maximum, mean and minimum monthly discharges, North Fork Nooksack River below Cascade Creek near Glacier, 1931-60.

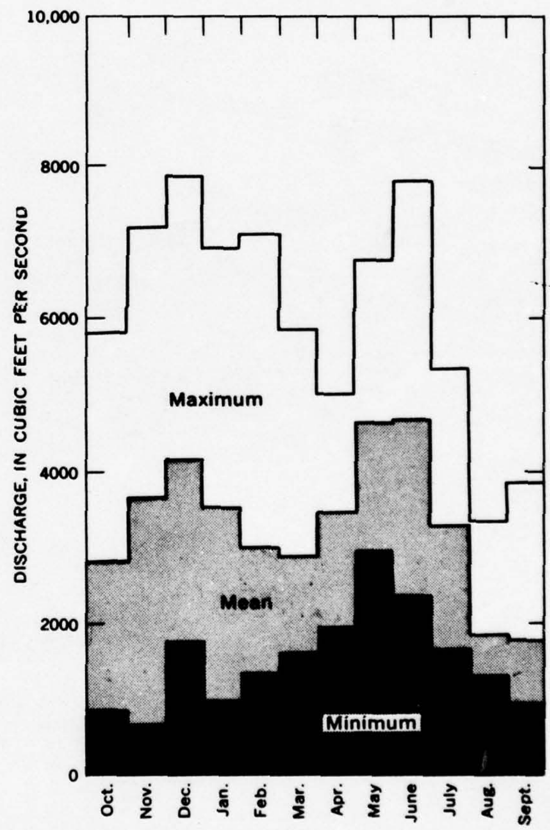



FIGURE 3-5. Maximum, mean and minimum monthly discharges, Nooksack River at Deming, 1931-60.

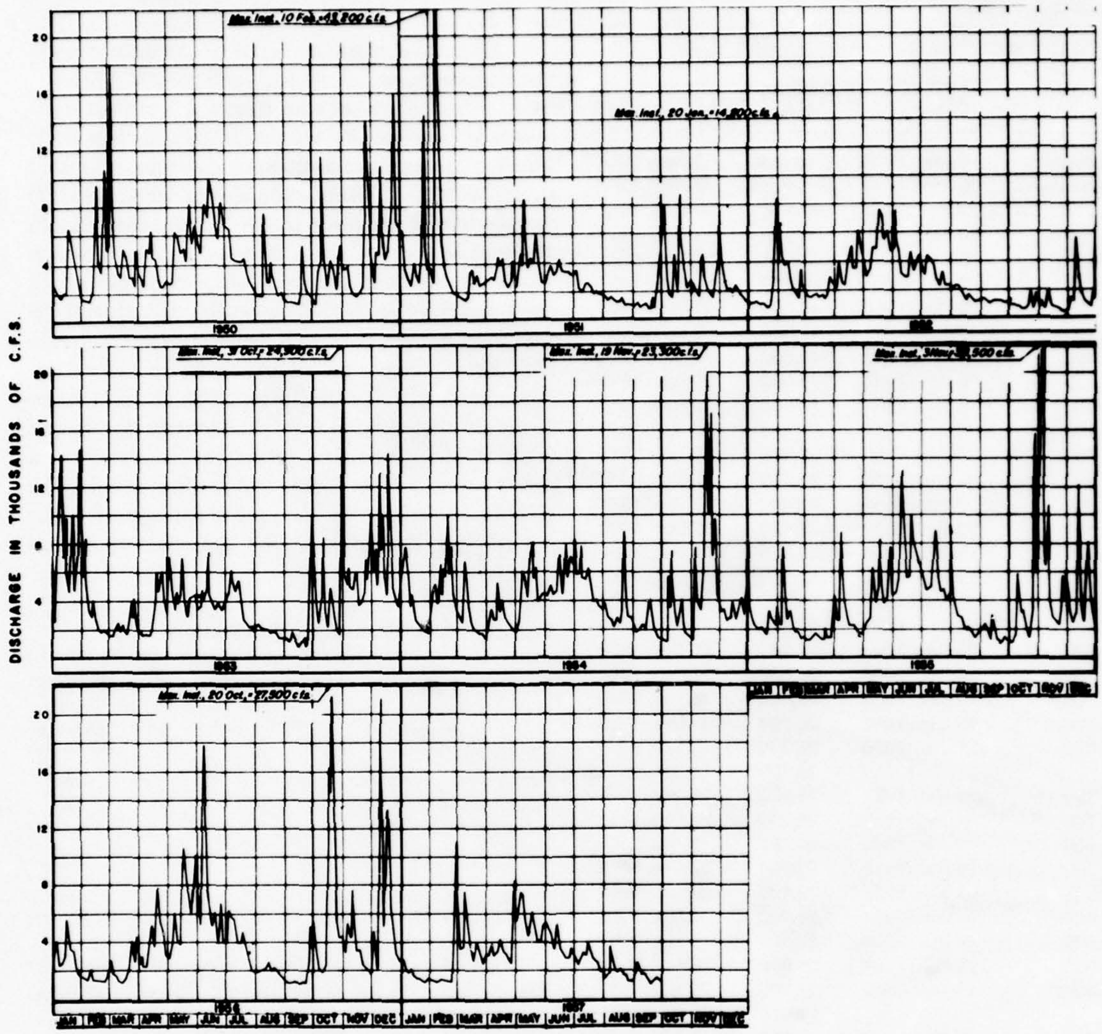


**FIGURE 3-6. Daily discharge hydrograph, Nooksack River at Deming**

**TABLE 3-6. Peak discharges greater than zero damage (19,000 cfs at Deming and near Lynden)**

| At Deming | | Near Lynden | |
|---|---|---|---|
| Discharge (cfs) | Date | Discharge (cfs) | Date |
| Unknown | 15 Mar. 1908 | Unknown | 1 Feb. 1924 |
| Unknown | 30 Nov. 1909 | Unknown | 27 Feb. 1932 |
| 49,300 (Est.) | 27 Feb. 1932 | Unknown | 29 Dec. 1917 |
| 43,200 | 10 Feb. 1951 | Unknown | 11 Dec. 1921 |
| 39,600 (Est.) | 25 Jan. 1935 | Unknown | 25 Jan. 1935 |
| 38,500 | 3 Nov. 1955 | 46,200 | 10 Feb. 1951 |
| 38,000 | 25 Oct. 1945 | 44,500 | 26 Oct. 1945 |
| 36,500 | 27 Nov. 1949 | 42,600 | 3 Nov. 1955 |
| 33,400 | 20 Nov. 1962 | 42,600 | 16 Jan. 1961 |
| 33,200 | 28 Oct. 1937 | 41,200 | 27 Nov. 1949 |
| 32,900 | 15 Jan. 1961 | 40,600 | 20 Nov. 1962 |
| 31,400 | 19 Oct. 1947 | 37,800 | 30 Apr. 1959 |
| 31,400 | 30 Apr. 1959 | 35,300 | 7 Jan. 1945 |
| 29,900 | 25 Oct. 1946 | 31,600 | 19 Oct. 1947 |
| 28,800 | 7 Jan. 1945 | 31,000 | 11 Dec. 1946 |
| 27,500 | 20 Oct. 1956 | 30,400 | 2 Dec. 1949 |
| 26,700 | 17 Oct. 1956 | 30,400 | 25 Dec. 1950 |
| 26,600 | 11 Dec. 1946 | 29,900 | 25 Oct. 1946 |
| 25,700 | 23 Nov. 1959 | 29,700 | 27 Nov. 1963 |
| 24,900 | 31 Oct. 1953 | 27,900 | 23 Nov. 1959 |
| 24,500 | 22 Oct. 1963 | 27,200 | 10 Dec. 1956 |
| 23,300 | 3 Dec. 1943 | 26,600 | 20 Oct. 1956 |
| 23,300 | 24 Dec. 1950 | 26,400 | 28 Dec. 1949 |
| 23,300 | 19 Nov. 1945 | 26,200 | 31 Oct. 1953 |
| 23,000 | 1 Jan. 1939 | 25,300 | 19 Nov. 1954 |
| | | 25,100 | 14 Dec. 1966 |
| 22,800 | 27 Nov. 1937 | 24,700 | 18 Oct. 1956 |
| 22,700 | 31 Jan. 1953 | 24,200 | 12 Nov. 1958 |
| 22,000 | 16 Jan. 1958 | 24,100 | 1 Feb. 1953 |
| 21,800 | 25 Oct. 1955 | 23,000 | 22 Nov. 1954 |
| 20,900 | 21 Jun. 1937 | 22,400 | 24 Jan. 1947 |
| 20,600 | 30 Dec. 1937 | 22,100 | 4 Mar. 1950 |
| 20,600 | 18 Apr. 1938 | 22,100 | 8 Jan. 1962 |
| 20,500 | 22 Nov. 1954 | 21,800 | 26 Jan. 1951 |
| 20,400 | 11 Dec. 1955 | 21,200 | 26 Nov. 1950 |
| | | 21,000 | 25 Oct. 1955 |
| 20,300 | 28 Dec. 1949 | 20,900 | 8 Feb. 1945 |
| 20,100 | 22 Dec. 1936 | 20,900 | 17 Jan. 1958 |

**TABLE 3-7. Major floods and estimated damages**

| Date or Frequency | Peak Discharge at Deming (cfs) | Average Recurrence Interval (Years) | Current Estimated Damages |
|---|---|---|---|
| 27 Nov. 1949 | 36,500 | 6 | $1,717,000 |
| 25 Oct. 1945 | 38,000 | 7 | 1,840,000 |
| 3 Nov. 1955 | 38,500 | 8 | 1,931,000 |
| 25 Jan. 1935 | 39,600 (Est.) | 9 | 1,972,000 |
| 10 Feb. 1951 | 43,200 | 12 | 2,256,000 |
| 50 Year Flood | 56,500 (Est.) | 50 | 4,149,200 |
| 100 Year Flood | 63,000 (Est.) | 100 | 5,014,800 |

Figures 3-7 and 3-8 show the estimated probability of annual maximum flows for the Nooksack River at Deming and near Lynden.

**Flood Damages**—A detailed examination was made of the Nooksack-Sumas flood plain in 1966 and an appraisal made of the damages that would be caused at that time by the discharges shown in Table 3-7. The average annual flood damages are estimated to be $853,000. This estimate includes $76,000 average annual damages in the Sumas River Basin. The greater part of flood damages in the Nooksack Valley is to lands, crops, farm equipment and buildings. Photograph 3-2 shows flooded agricultural land near Lynden during the February 1951 flood. In the delta, levees are occasionally breached by impounded flood waters, resulting in salt water intrusion that may reduce productivity for several years. Flood flows also erode the riverbanks and overtop and damage levees and roadways. Table 3-8 gives flood damages by the general damage categories discussed in the Puget Sound Area Section of this appendix.

**TABLE 3-8. Flood damage distribution**

| Category | Percent of Total Damage |
|---|---|
| Agricultural | 56 |
| Buildings and equipment | 29 |
| Transportation facilities | 7 |
| Other | 8 |
| Total Losses and Damages | 100 |

The extent of flooding at progressive riverflows and stages is shown in Figure 3-9. Stages and flows are referenced to the gage at Deming.

## Existing Flood Control Measures

**Flood Forecasting and Warning**—Flood forecasting is a service of the U.S. Weather Bureau. The snowpack, temperature, and precipitation information supplied by climatological stations in and adjacent to the basin are used in conjunction with weather forecasts to predict flooding conditions on the river. Whenever the Nooksack River at the Deming gage is forecast to exceed a stage of 12 feet, the Weather Bureau alerts the Whatcom County Engineer, Civil Defense Director, and Red Cross officials in Bellingham by telephone. Local radio, television, and press facilities are informed of the

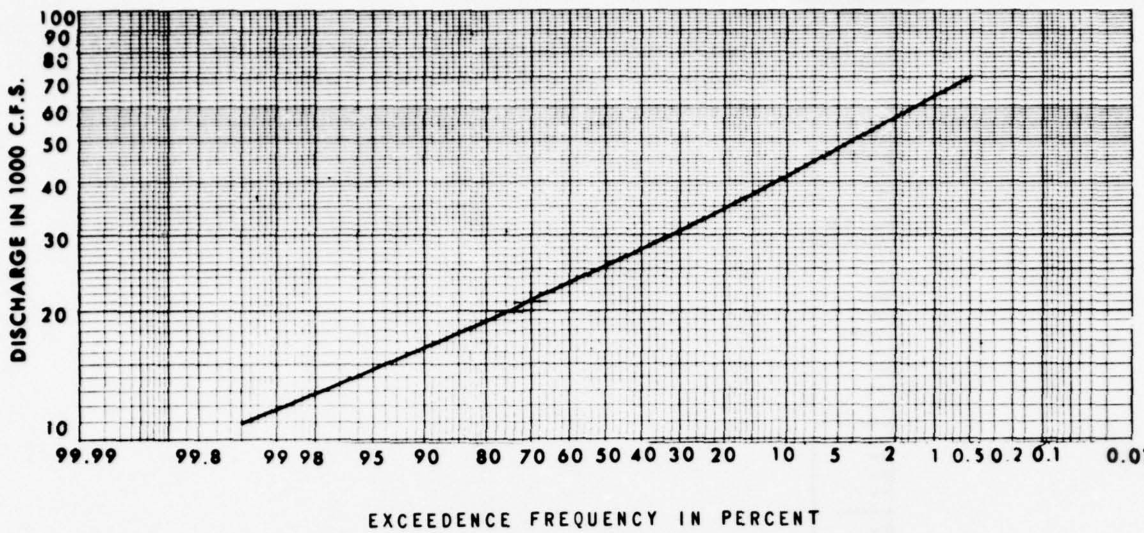



FIGURE 3-7. Frequency curve of annual maximum peak flows, Nooksack River at Deming

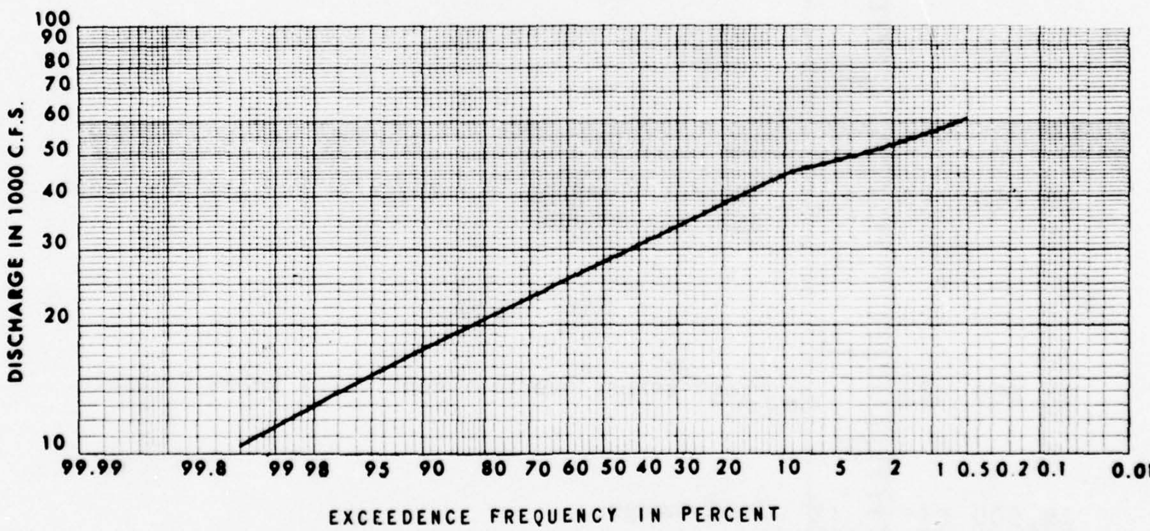



FIGURE 3-8. Frequency curve of annual maximum peak flows, Nooksack River near Lynden

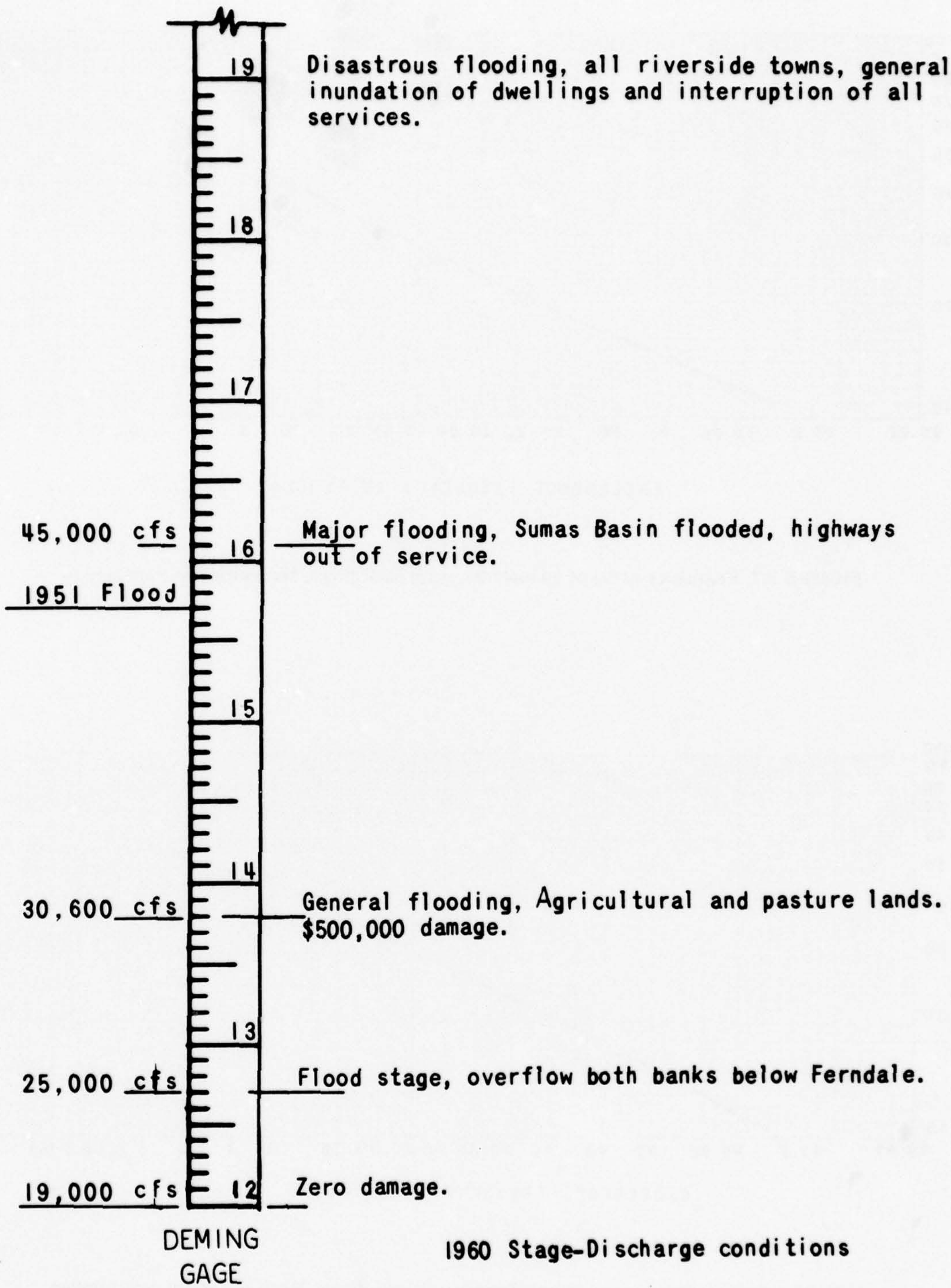



**FIGURE 3-9. Progressive stages of flooding, Nooksack River.**

**PHOTO 3-2. 1951 Flood at Lynden. View is west, showing Stickney Island area to the right. Flood waters are receding. (Corps of Engineers Photo 11 February 1951)**

situation through the use of local teletype circuits. Interested State agencies such as Civil Defense, the Highway Department and the State Patrol also are informed of the forecast by telephone.

**Flood Protective Works**

**Levees**—Table 3-9 gives the location of levees and the level of protection provided.

**TABLE 3-9. Protection provided by existing levees**

| | | Protection | | |
|---|---|---|---|---|
| Location | Miles of Levee | Flow (cfs) | Gage | Recurrence Interval (Years) |
| Right Bank at No. Cedarville (RM 31) | 0.5 | 22,000 | Deming | 2 |
| Right Bank at Everson (RM 22) | 0.9 | 33,000 | Deming | 4 |
| Left Bank (RM 13.5 to RM 22) | 5.4 | 19,000 | Deming | 1 |
| Right Bank (RM 16 to RM 21) | 4.1 | 19,000 | Deming | 1 |
| Right Bank (RM 7 to RM 16) | 8.9 | 18,000 | Lynden | 1 |
| Left Bank RM 6 to RM 13) | 5.3 | 22,000 | Lynden | 1 |
| Left Bank (RM 0 to RM 6) | 3.3 | 27,000 | Lynden | 2 |
| Right Bank (RM 7 to RM 1 & both sides of Lummi River | 14.0 | 29,000 | Lynden | 2 |
| Total | 42.4 | | | |

The town of Everson constructed a levee along the right bank of the Nooksack River from the Milwaukee Railroad bridge across the normal overflow path to high ground. This levee has effectively deflected floodwater from the main part of Everson and reduced the amount of overflow into the Sumas Basin.

The U.S. Bureau of Indian Affairs developed a flood control project on the Lummi Indian Reservation, including levees and an intake structure at the head of the Lummi River.

**Channel Improvement**—The McCauley Creek Flood Control District is located on the right side of the Nooksack River at Deming. Here three creeks, Mitchell, Smith, and McCauley, flow out of the hills and across the valley floor to join the Nooksack River. These creeks were previously capable of flooding the Deming area during periods of heavy precipitation. The flood control district prevents flooding by maintaining a stabilized channel of sufficient capacity to carry the flow from all three creeks to the river.

**Bank Protection**—To reduce the loss of farm lands from bank erosion, property owners have constructed extensive bank protective works with assistance from the Agricultural Stabilization and Conservation Service. The State and Whatcom County have also contributed to and constructed bank protection projects. The Corps of Engineers has performed emergency bank protection work at 13 locations resulting in total expenditures of $305,300.

**Flood Plain Management**—The Corps of Engineers, at the request of the State of Washington, published a Flood Plain Information Study in January 1964, covering the Nooksack River Basin. Whatcom County is using information from this report to plan future uses of flood plain lands.

## Flood Problems

**Nooksack River**—Large, scattered areas are subject to local flooding annually. The remainder of the flood plain is subject to flooding about once in 2 to 5 years. The flood plain is utilized almost entirely for agriculture and contains many farm buildings and residences, as well as portions of the communities of Everson, Ferndale, Marietta and Lynden. Zero damage flow is considered to be about 19,000 cfs at the Deming gage. When flows reach 25,000 cfs at Deming, the levees at the head of the Lummi River become vulnerable. When flows reach 35,000 cfs at Deming, the Nooksack River may overflow into the Sumas Basin upstream from Everson.

Maximum recorded flow experienced at Deming was 43,200 cfs, in 1951. At this discharge most of the flood plain is inundated. Along the South Fork and downstream to near Everson the flooded area is an irregular strip about one-half mile wide. Between the constrictions at Everson and Ferndale the water surface varies from one to two miles in width, and downstream from Ferndale the delta is covered for a width of three to four miles.

In the agricultural setting of the Nooksack valley the greater part of flood damages is to land and crops. This results from drowning of grasses and other plants, loss of livestock, erosion of banks and fallow ground, leaching of fertilizer, infestations by weed seed, carrying away of fences, deposition of sand, gravel, and driftwood, and temporary loss of use of pasture because of ground saturation. A special situation occurs in the delta when tidal dikes are breached by impounded river waters. The resulting salt water intrusion may reduce productivity for several years. Next in order of importance are damages to buildings, particularly in the low portions of cities and towns and to a lesser extent on farms. Damage to levees by erosion and overtopping is a significant item. Roadways suffer erosion of embankments and shoulders, undermining of pavement, and a temporary weakening because of subgrade saturation. Restrictions to travel may cause financial losses. In the upper reaches of the valley above Everson, flood damages consist chiefly of bank erosion and the deposition of sand and gravel on farm lands.

**Small Tributary Streams**—Anderson Creek enters the Nooksack from the south several miles downstream from Lawrence. The stream drops about 2,700 feet in its upper four miles and only 200 feet in the lower four miles. The abrupt flattening of the gradient results in the deposition of sediment and overbank flooding.

Fishtrap and Bertrand Creeks rise in Canada and join the Nooksack about four miles west of Lynden. Their lower flood plains are common to the flood plain of the Nooksack River. Both creeks do considerable bank cutting and much of the sediment they carry is deposited in their lower reaches where they cross the Nooksack flood plain. Overbank flooding is experienced annually. The Soil Conservation Service has been requested to make a study, under Public Law 566 of the problems on these streams.

Silver Creek joins the Nooksack near its mouth north of Marietta. The creek drains an agricultural area of 9,186 acres northwest of Bellingham. In the lower two miles, bottom land adjacent to the Nooksack River is flooded frequently by creek overflow and occasionally by overflow of the Nooksack River. In the upper reaches of the creek large areas are subject to inundation damaging houses and farm buildings.

# PRESENT AND FUTURE NEEDS

## Evaluation of Present Situation

An area of 49,000 acres in the flood plain of the Nooksack-Sumas Basins is subject to flooding. Some of the land is flooded every year. The 1951 flood, the largest of record, inundated 26,800 acres of which 17,700 acres were in use for agriculture. In addition to crops, farm land, and farm buildings, damages occur to buildings and other improvements on low ground in the vicinity of Marietta, Ferndale, Lynden, Everson, and Sumas. Flood damage begins when flows reach 19,000 cfs at Deming. Average annual flood damages amount to $853,000 and include damages to land, crops, livestock, buildings, improvements, equipment and transportation facilities.

The existing 42.4 miles of levee along the Nooksack are 3 to 6 feet in height, provide varying

degrees of protection, but are all likely to be overtopped on an average of every 5 years. There are no storage reservoirs in the basin to regulate flows and recorded river discharges at Deming have fluctuated from 500 cfs to 43,000 cfs.

## Flood Control Needs

**Prevention of Flood Damages**—The 49,000-acre flood plain of the Nooksack-Sumas Basins needs increased flood protection for existing developments. Average annual damages at 1966 prices and conditions are estimated to be $853,000 and the damage that would result from a flood with an estimated frequency of 100 years is estimated to be $5,000,000. Losses of this magnitude are expected to be reduced by increasing the existing level of flood protection. Flood plains should be zoned to insure that future development of these lands is orderly and consistent with the protection provided.

Based on the methodology and considerations previously discussed for the Puget Sound Area, anticipated flood damages in the flood plains of the Nooksack River Basin are expected to increase by the percentages as shown in Table 3-10.

**TABLE 3-10. Percentage increases in productivity levels and developments for specified periods**

| Category of Damage | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Agriculture | 25 | 28 | 25 |
| Non-Agriculture | 60 | 100 | 100 |

**TABLE 3-11. Existing and future annual damages (in thousands of dollars)**

| Category | Under Development Levels of 1966 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Agriculture | 480 | 600 | 770 | 960 |
| Buildings & Equipment | 250 | 410 | 810 | 1,600 |
| Transportation Facilities | 66 | 110 | 210 | 420 |
| Other | 57 | 90 | 180 | 370 |
| Total | 853 | 1,210 | 1,970 | 3,350 |

Application of these percentages to the average annual damages based on 1966 prices and conditions provides an indication of future damages at 1966 prices without additional flood protection. Table 3-11 shows that the combination of all categories of damage are expected to increase from about $853,000 in 1966 to about $3,350,000 by the year 2020.

**Optimum Flood Plain Use**

**Agriculture**—The amount of farm land in the flood plain is expected to remain relatively constant in the future. The increase in value will result from better productivity, the addition of new farm buildings and equipment, and some conversion to higher value crops. When economically feasible, protection against at least 25-year frequency floods should be provided for agricultural lands.

**Intensive Land Use**—Although there is no urgent necessity for expansion of existing communities into the flood plain, this is taking place in the vicinity of Ferndale, Lynden and Everson. At Ferndale there is a commercial section subject to inundation in the south part of town and residential construction continues to take place near the river to the north. The entire Stickney Island area between Lynden and Everson is gradually being built upon. The town of Sumas is flooded whenever substantial overflow from the Nooksack River to the Sumas River occurs.

Population in the basin is projected to increase to 168,700 by the year 2020, with an intensive land use density of 4.0 persons per acre, resulting in a total of 45,000 acres of land being put to intensive uses. This development can be, and should be, guided to those areas which are best able to handle each use.

Industrial land use needs are projections of the type of uses existing today. Future land needs will come from the pulp and paper industry, wood products industry, aluminum industry and the oil industry. There will be a need for expansion and further development of a deep-water port facility within the Nooksack-Sumas Basins which will require an additional large plot of land. Since so many industries require water access, a special effort is needed by all concerned to plan for industrial sites in prime locations that do have water access, and the necessary adjacent lands to house today's and tomorrow's industries. Industrial use of fertile flood plain lands should be avoided but if selected must be provided at least a 100-year level of flood protection.

## Summary of Flood Control Needs

There is a need to reduce the present average annual flood damages of $853,000 that occurs to croplands, dwellings, roads and utilities in the flood plain. The trend of development within the basin is

expected to result in the future growth of flood damages approximating 2½ percent compounded annually if additional flood control is not provided. Future growth of average annual flood damages are expected to be $1,210,000 in 1980, $1,970,000 in *2000, and $3,350,000 in 2020.*

Additional flood control is desirable to protect the increasingly valuable agricultural investment and urban and industrial developments in the Nooksack-Sumas flood plain. More intensive agriculture can be expected in the future by conversion to higher value crops. Existing levees provide varying degrees of flood protection but are all likely to be overtopped on an average of once every 5 years. Protection of at least a twenty-five year level should be provided to these agricultural lands. A one-hundred year level of protection should be provided to industrial and urban developments at and near the towns of Ferndale, Everson, Nooksack, and Sumas. The entire flood plain should be managed to insure that land use is compatible with the degree of flood protection provided.

## MEANS TO SATISFY NEEDS

### *Flood Control Objectives*

The flood control objectives are to meet the needs set forth in the preceding section by providing flood control through utilization of both structural and nonstructural measures. Objectives of structural measures are shown below in Table 3-12. Nonstructural measures would include a flood plain warning system and flood plain management consistent with the flood protection provided.

### Opportunities For Structural Measures

**Upstream Storage**—Approximately 210,000 acre-feet of flood control storage is required to provide a 100-year level of flood control in the basin. Most of the required storage could be provided at the Deming site located just below the confluence of the North and South Forks. Alternative storage could be developed at the Welcome, Rocky Ridge, Warnick, Glacier and North Fork sites on the North Fork of the Nooksack River and at the Edfro site on the South Fork of the Nooksack River. The most feasible sites on these forks are the Edfro site on the South Fork and the North Fork site located above Nooksack Falls on the North Fork. The Edfro site could provide 63,000 acre-feet of effective flood control storage and the North Fork site could provide 21,000 acre-feet of effective flood control storage.

**Levees and Channelization**—Flood control by major levee construction is effective for protection of urban areas extending into the flood plain such as Marietta, Ferndale, Everson, Nooksack and Sumas. Levees would also be effective in controlling floods in major agricultural areas along both banks of the Nooksack River.

### Solution To Flood Control Needs

**General**—Features of the flood control plan are detailed in Table 3-13 and shown on Figure 3-10. Upstream storage, levee and channel improvements, and flood plain management are the nucleus of this plan. The flood control plan would provide for optimum development and protection through the year 2020. Features of this plan are described as single purpose flood control. Economic justification may depend on consideration of other water resource needs.

**TABLE 3-12. Objectives of structural measures**

| Flood Plain Designation | Levels of Protection[1] 100 Year | 25 Year | Less Than 25 Year |
|---|---|---|---|
| 6,200 acres along right bank below Ferndale | | X | |
| 5,000 acres along left bank opposite Lynden | | X | |
| 5,000 acres along right bank—Lynden to Everson | | X | |
| 3,000 acres in Sumas flood plain which floods from overflow of Nooksack River | | X | |
| Portions of communities of Acme, Clipper, Deming, Everson, Nooksack, Sumas, Lynden, Ferndale and Marietta | X | | |
| 4,000 acres along right and left banks South Fork river mile 0 to river mile 12 | | X | |
| 23,800 acres including the rivers designated floodway | | | X |

[1] For floods that can be expected to occur on an average of once in the period designated.

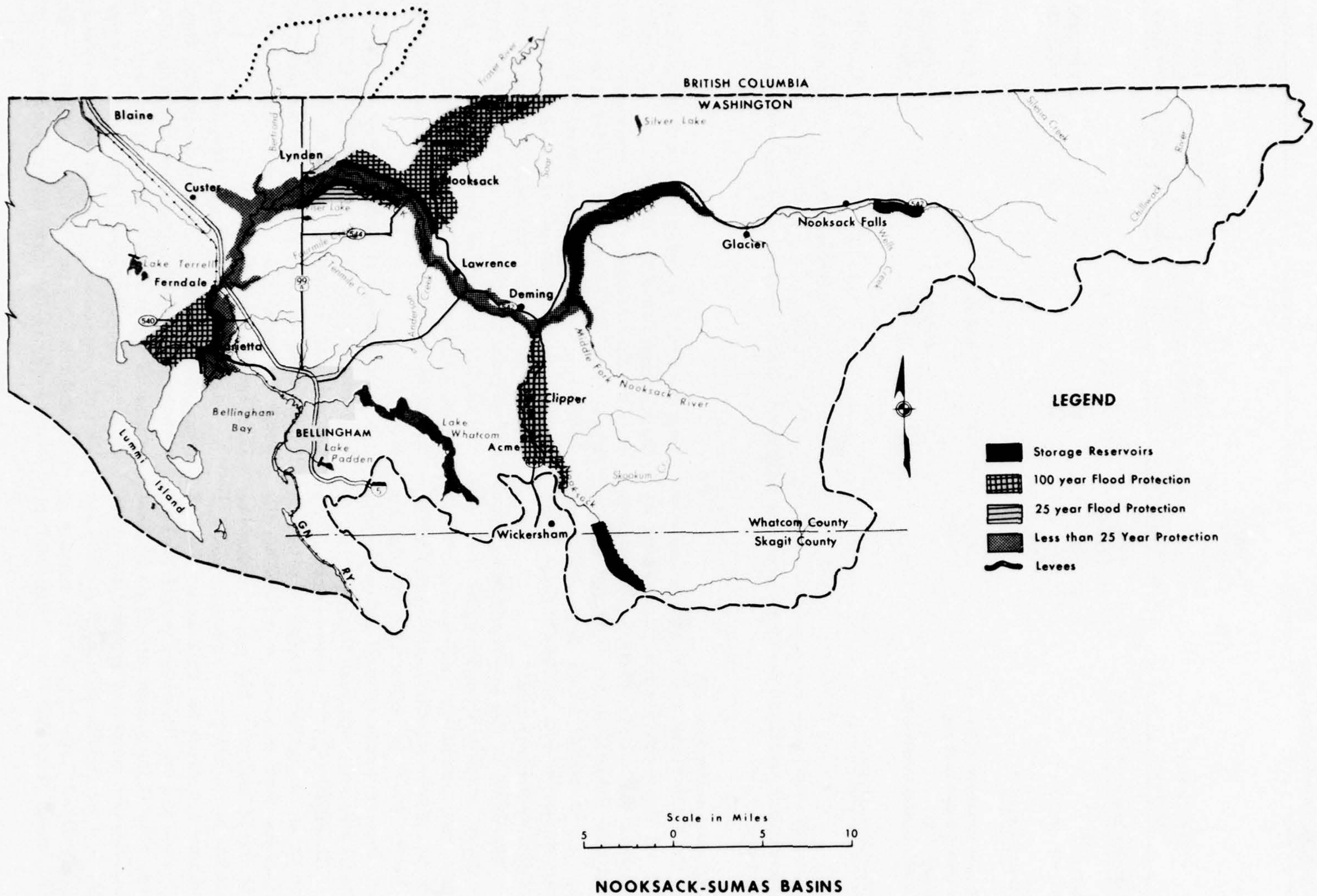



**FIGURE 3-10. Proposed flood control plan and accomplishments**

**TABLE 3-13. Flood control plan**

| Flood Control Feature | Effective Flood Control Storage Acre-Feet | River Mile | Height of Dam Feet | Design Capacity cfs | Sequence of Development To 1980 | To 2000 | To 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|---|---|---|---|
| Flood Control Storage Projects | | | | | | | | |
| Edfro Dam | 63,000 | 15.2 | 170 | | X | | | $27,200,000 |
| North Fork Dam | 21,000 | 65 | 200 | | | X | | 21,400,000 |
| Levee Construction | | | | | | | | |
| Right bank below Ferndale—6 mi. | | | | 47,000 | X | | | 2,500,000 |
| Right bank Lynden to above Everson—7 mi. | | | | 47,000 | | X | | 3,500,000 |
| Left bank opposite Lynden—10 mi. | | | | 25,000 | | X | | 5,000,000 |
| Flood Plain Management | | | | | X | X | X | 6,000[1] |
| | | | | Total Cost of Plan | | | | $59,606,000 |

[1] Whatcom County and State of Washington implementation costs only. Cost of completed Flood Plain Information Study not included.

**Sequence of Development**

**To 1980**—Flood control storage could be provided on the South Fork Nooksack River by construction of Edfro Dam. Six miles of levees along the right bank below Ferndale could also be constructed in this period. Flood plain zoning and regulation compatible with the level of flood protection provided should be adopted.

**1980-2000**—In this period additional flood control should be provided so flood plain lands can be farmed more intensively. Additional protection could be provided by construction of the North Fork Dam. Levees could be constructed on the left riverbank from river mile 13 to 23 and on the right bank from Lynden to upstream of Everson.

**2000-2020**—By this period demand for intensive use of the flood plain is expected to be such that additional protection may be required for the lower Nooksack flood plain. This protection could be accomplished by construction of levees as needed.

**Economic Analysis for 1980 Level of Flood Control**—Costs and benefits are shown in Table 3-14. Additonal benefits for storage projects could result from inclusion of other project purposes. Also shown in Table 3-14 are benefits and costs for levee and channel improvement works to be constructed prior to 1980. Annual costs include amortization of the total investment (including interest during construction), average annual cost of operation and maintenance, and the equivalent average annual cost of major replacements. An interest rate of 4-5/8 percent was used to compute interest during construction and the annual cost of interest and amortization. An economic life of 100 years was used for storage projects and an economic life of 50 years was used for levee construction. Benefits are based on 1966 prices and include future growth. The 1980 projects are considered to be constructed at or near the same time period.

**Accomplishments**—Accomplishments of the flood control plan are shown in Table 3-15. One-hundred year protection would be provided to 15,000 acres by 1980. Twenty-five year protection would be provided to 8,000 acres by 1980 and 15,000 acres by the year 2000.

**Alternatives Considered**—Levee and channel improvements only as a means to provide flood protection was found to lack economic justification because of the extensive work required to provide protection from unregulated peak flows. Investigations of flood control storage were made for a site on the Nooksack River near Deming, for 10 sites on the North Fork and tributaries thereto, for two sites on

**TABLE 3-14. Estimated costs and benefits for projects to be constructed prior to 1980**

| Project | Estimated[3] Total Construction Costs | Estimated[3] Annual Cost | Estimated Annual Flood Damage Prevention Benefits | Estimated Annual Land Enhancement Benefits | Total Annual Benefits |
|---|---|---|---|---|---|
| Edfro Dam | $27,200,000 | $1,540,000 | $1,001,000 | $173,000 | $1,174,000 |
| Levee, downstream of Ferndale | 2,500,000 | 132,500 | 141,000 | 0 | 141,000 |
| Flood Plain Management | -- | 3,600[1] | 1,000,000[2] | 0 | 100,000 |
| Total | $29,700,000 | $1,676,100 | $1,242,000 | $173,000 | $1,415,000 |

[1] Includes Federal, Whatcom County, and State of Washington administration and enforcement costs.

[2] Based on reduction of future flood damages in the buildings and equipment category.

[3] 1968 price level.

**TABLE 3-15. Accomplishments of flood control plan**

| | To 1980 | To 2000 | To 2020 |
|---|---|---|---|
| Acreage Protected by Structural Measures | | | |
| 100 year protection | 15,000 | 18,000 | 18,000 |
| 25-50 year protection | 8,000 | 15,000 | 15,000 |
| Less than 25 year | 26,000 | 16,000 | 16,000 |
| Flood Plain Management (Acres) | 34,000 | 31,000 | 31,000 |
| Flood Damage Prevention (Dollars) | | | |
| Projected average annual flood damages without additional protection | 1,210,000 | 1,970,000 | 3,350,000 |
| Reduction in future average annual flood damages due to flood plain management | 80,000 | 280,000 | 675,000 |
| Projected residual average annual flood damages with flood plain management | 1,130,000 | 1,690,000 | 2,675,000 |
| Reduction in future average annual flood damages with implementation of structural measures | 829,000 | 1,430,000 | 2,270,000 |
| Residual average annual flood damages | 301,000 | 260,000 | 405,000 |

the Middle Fork, and for three sites on the South Fork. The most feasible of the potential sites were found to be the Edfro site on the South Fork and the North Fork site located above Nooksack Falls.

Diversion of the Nooksack River to the Lummi River was investigated and determined to be economically infeasible primarily because of extensive transportation system relocation costs.

Permanent evacuation of the flood plain was considered but determined infeasible. Purchase of flood plain lands and relocation of existing developments and facilities would be required. Major relocations would be excessively expensive and unacceptable to a majority of the residents in the valley.

Floodproofing of existing buildings was evaluated as an alternative to major flood protective works for reduction of present flood damages. Extensive existing urban and industrial developments in the communities of Acme, Clipper, Deming, Everson, Nooksack, Sumas, Lynden, Ferndale and Marietta as well as numerous residences and associated buildings located in rural areas of the flood plain would require

floodproofing. Approximately 25 percent of the estimated $853,000 average annual flood damages or about $210,000 occurs to buildings. The majority of these buildings are of wood frame construction and floodproofing would require structural treatment that would be economically infeasible.

### Summary

The 49,000-acre flood plain of the Nooksack River is subject to frequent overbank flooding. The February 1951 flood with an estimated recurrence interval of 12 years resulted in estimated damages of $2,256,000. Average annual flood damages are estimated to be $853,000 based on 1966 prices and conditions and occur to crops, farm land, buildings, equipment and transportation facilities.

Anticipated growth in the flood plain indicates that future flood damages could increase if additional protection is not provided. Average annual flood damages under future conditions are estimated to be $1,210,000 in 1980, $1,970,000 in 2000, and $3,350,000 in 2020.

Implementation of the flood control plan would significantly reduce flood plain damages and permit optimum utilization of the flood plain. One-hundred year protection would be provided to the South Fork of the Nooksack River flood plain, to the Sumas Basin flood plain, and to the right bank flood plain below Ferndale. Prime agricultural lands would be provided 25-50 year protection. Urban developments extending into the flood plain at the communities of Acme, Clipper, Deming, Everson, Nooksack, Sumas, Lynden and Ferndale would be provided 100-year protection.

# SUMAS RIVER BASIN

## PRESENT STATUS

### Stream System

The Sumas River Basin is about 20 miles long, has a maximum width of about 10 miles, and covers a total area of 143 square miles. Seventy-three square miles of the basin are in Whatcom County in the United States and the remainder in British Columbia, Canada. Within the State of Washington the Sumas River-Johnson Creek Valley is about 11 miles long and a maximum of 3.5 miles wide.

The Sumas River rises in the southern part of the basin and winds northward 19 miles to the International Boundary, 18 river miles south of its junction with the Fraser River.

The principal tributaries within the United States are Johnson and Saar Creeks. Johnson Creek drains about 15,000 acres in the western part of the basin, and flows northeasterly to the city of Sumas, then easterly 0.5 mile to its junction with the Sumas River. Saar Creek drains 11,000 acres in the northeastern part of the basin, and joins the Sumas in British Columbia.

### Flood Plain

The Nooksack River which now discharges in Puget Sound near Bellingham, Washington, once flowed northward through the Sumas Valley to the Fraser River on its way to the sea. There is no evidence that the Nooksack has followed this path since the last glacial period; however, the Nooksack appears to be aggrading the lowlands slowly by overbank deposition during flood stages, and Johnson Creek in the western part of the basin is undoubtedly cutting downward. The low water channel of the Nooksack River lies within 1,000 feet of the Nooksack-Sumas divide at several points between the station of Lawrence and the city of Everson. At bankfull stages, the river is less than 300 feet from the divide, along most of this reach. The Nooksack has been cutting its way toward the Sumas drainage basin for many years, and the tendency for the Nooksack River to spill over the divide, just south of Everson, into Johnson Creek will increase slowly over the years. Upon the release of a log jam on the Nooksack River during a flood, the sudden rush of water could cause sufficient erosive action to cut a substantial channel to Johnson Creek.

The Canadian portion of the Sumas valley originally was below high flows of the Fraser River and was flooded each year. Saar Creek and the Sumas and Vedder Rivers discharged into Sumas Lake, a large, shallow lake with an area of about 20,000 acres. Early in 1930, this part of the valley was reclaimed by diking along the Fraser River, draining Sumas Lake and construction of a diversion canal for

the Vedder River. The valley has not been flooded by the Fraser River since completion of this work.

The only incorporated cities in the basin are Sumas, Nooksack, and Everson, which have a combined population of about 1,600. The total population of the valley within the State of Washington is approximately 5,000. Sumas is a transportation hub for three railroads and a point of entry between Canada and the United States. Everson is on the north bank of the Nooksack River, on the low divide which separates the Sumas and Nooksack drainage basins as shown on Figure 3-1. The city of Nooksack is about one mile east of Everson. Most of the land in the Sumas River valley which is suitable for agriculture, has been developed. Farming is modern, diversified and intensive. Dairying is the most important agricultural enterprise. Of the 1,900 acres of farm land in the United States' portion of the Sumas valley, about 80 percent is in pasture and the remainder is in vegetable and fruit crops.

Branch lines of the Northern Pacific and the Chicago, Milwaukee, St. Paul and Pacific Railroads, connecting with the Canadian Pacific Railroad at the city of Sumas, serve the Sumas River Basin. Except in the vicinity of Sumas, both branch lines are on earth embankment not subject to flooding. State Highway 9, the principal north-south highway, enters the basin 4 miles south of Everson and continues through Nooksack to Sumas. A 2-mile section of the British Columbia Highway extends north from Sumas across the Canadian part of the basin and connects with the Trans-Canada Highway. State Highway 546 extends west across the basin to U.S. Highway 99A from an intersection with State Highway 9, two miles south of the city of Sumas. A network of surfaced farm-to-market roads connects all populated areas.

## History of Flooding

**Flood Characteristics**–Extensive flooding of the Sumas Valley occurs when the Nooksack River overflows the low divide separating the drainage basins. Log and ice jams in the Nooksack River below the Deming gaging station have contributed to the problem. Overflow occurs when the Nooksack River reaches a discharge of approximately 35,000 cfs at the Deming gage. Overflow into the Sumas Basin is partially prevented by a Northern Pacific Railroad embankment which follows the divide between Everson and the railroad embankment has been overtopped several times. After overtopping the divide, flood water flows northward into Johnson Creek through a low swale between Everson and Nooksack. When the overflow exceeds the carrying capacity of the creek, the excess spreads overland, flooding several hundred acres, many farms and suburban homes, and flows northeastward through the city of Sumas into Canada. Sumas is situated on relatively flat ground and the entire city is susceptible to flooding. Since its incorporation in 1891 the city has been flooded seven times by the Nooksack River.

Relatively minor overbank flooding occurs almost every year in several places along the Sumas River and its tributaries but is normally confined to low, undeveloped areas. Local interests, in cooperation with the Soil Conservation Service, are completing a program of land treatment measures and channel improvements in the Saar Creek watershed. All other streams in the basin are unimproved and flow through shallow, winding channels which have insufficient capacity to contain storm runoff. At many locations, stream channels are seriously obstructed by willows, brush and debris which restrict the passage of floodwater and promote the accumulation of debris jams.

**Floods**–The most widespread flood of record in the Sumas Basin occurred in January 1935. The flood resulted from heavy precipitation, warm temperatures and snowmelt in the Mount Baker area. The estimated peak discharge at Deming was 39,600 cfs. The Nooksack-Sumas divide was overtopped by the Nooksack River inthe vicinity of Everson, and all of the Sumas valley was flooded. In Washington, about 1,500 acres of pasture, 350 acres of grain land, 440 acres of swamp and timberland, the entire town of Sumas and parts of Everson and Nooksack were under water. In the Canadian part of the valley, more than 12,700 acres of cropland were flooded and approximately 350 persons driven from their homes. Many highways were impassable and both railroad lines in the valley were out of service.

In October 1937 the peak discharge of the Nooksack at Deming was 33,200 cfs, and runoff was high throughout the Nooksack basin. However, the high flow was of short duration and overflow into the Sumas basin was negligible.

The flood of 27 November 1949 was typical of floods caused by intense rain storms. Minor rises resulted from heavy rainfall which occurred on 22 and 25 November. As relatively high temperatures prevailed during these storms, no snow blanket was formed and the soil became saturated and conducive to rapid runoff. The Nooksack River discharge at

Deming increased from 10,000 cfs on 26 November to 36,500 cfs on 27 November, and was in excess of 30,000 cfs for approximately eight hours. Approximately 320 cfs overflowed into the Sumas valley at the peak and caused minor flooding.

The most serious flooding of the Sumas Basin in recent years occurred in 1951. On 10 February, with a peak flow of 43,200 cfs recorded at Deming, the Nooksack River began flooding the Sumas River valley just south of Everson. By the 11th of February, water was in the streets of Sumas, four feet deep in some areas. Twenty-three city blocks were flooded, and several families were evacuated. The entire flood sequence occurred in about 7 days, from the initial rise until the return to normal flows. Approximately 1,400 cfs overflowed into the Sumas Basin at the floods peak discharge.

**Flood Damages**—A detailed examination of the Sumas flood plain was made in 1966, and an appraisal made to determine damages that would result from Nooksack River overflows with the same magnitude as the February 1951 flood and those having a recurrence interval of once in 50 and 100 years. Areas in the Sumas valley subject to inundation by these floodflows and the estimated damages at 1966 prices and conditions are tabulated in Table 3-16.

**TABLE 3-16. Major floods and estimated damages**

| Recurrence Interval (Years) | Peak Discharge of Nooksack at Deming (cfs) | Inundated Area in Sumas Valley (Acres) | Current Estimated Damage |
|---|---|---|---|
| 12 (10 Feb. 51) | 43,200 | 2,023 | $ 276,000 |
| 50 | 56,500 (Est.) | 5,761 | 1,025,000 |
| 100 | 63,000 (Est.) | 6,534 | 1,558,000 |

The damages shown are included in the total damages given in Table 3-7. Average annual flood damages in the Sumas River Basin within the U.S. are estimated to be $76,000. The greater part of the damage is to lands and crops. The remainder is to buildings in the vicinity of Sumas and to farm buildings and residences.

## Existing Flood Control Measures

**Flood Forecasting and Warning**—Flood forecasts and warning for the Sumas Basin are provided by the U.S. Weather Bureau, and are similar to those for the Nooksack River Basin.

**Flood Protective Works**—A project authorized under the provisions of Public Law 566 is being constructed along 3.7 miles of Saar Creek and 6.5 miles of Mud Creek by local interests in cooperation with the U.S. Soil Conservation Service. The project consists of land treatment measures, such as drainage facilities and channel improvements.

About 1940, the city of Everson, in cooperation with Whatcom County, constructed an earth levee on the right bank of the Nooksack River at Everson to prevent the Nooksack River from overflowing into the city and the Sumas Valley at Everson. The levee extends upstream about 2,000 feet from the Chicago, Milwaukee, St. Paul and Pacific Railroad bridge.

Channel improvements in the Sumas River Basin have consisted primarily of channel widening and straightening at several locations.

**Flood Plain Management**—The Corps of Engineers, at the request of the State of Washington, published the Sumas River Flood Plain Information Study report in June 1966 as a supplement to the Flood Plain Information Study report on the Nooksack River Basin. The report contains the same type of information previously described for the Nooksack study.

## Flood Problems

**Overflows from Nooksack River**—Extensive *flooding of the Sumas Valley occurs when the* Nooksack overflows the low divide separating the drainage basins. The expected recurrence interval is once in every 10 years. After overtopping the divide, floodwaters flow northward into Johnson Creek through a shallow swale between the towns of Everson and Nooksack. Johnson Creek is a shallow drainage course with limited carrying capacity and overflows from the Nooksack spread overland, flooding farm lands, suburban home developments and the city of Sumas. Sumas is on relatively flat ground and the entire city is susceptible to flooding.

**Sumas River and Tributaries**—Minor flooding occurs almost every year on the Sumas River and its tributaries, but usually is confined to low, undeveloped areas. Except for Saar Creek, tributary streams in the basin are unimproved and are characterized by shallow, winding channels which have insufficient capacity to contain storm runoff. At many locations, brush and debris in stream channels restrict the passage of floodwater and cause debris jams. In recent years a landslide has occurred near the headwaters of

Swift Creek. Glacial sediments have been removed by floodwaters from this slide leaving masses of rocks and boulders in the streambed and upper flood plain. These sediments have formed an alluvial fan on the Sumas River flood plain and have elevated the Swift Creek channel above the Sumas River channel. Other streams (Dale and Breckenridge Creeks) originating on Sumas Mountain have the same slide potential.

## PRESENT AND FUTURE NEEDS

### Evaluation of Present Situation

The flood plain of the Sumas River is subject to frequent flooding by overflow from the Nooksack River. The average annual flood damage for this basin is $76,000 and is included with the $853,000 indicated for the Nooksack Basin. The flood plain is used primarily for agricultural pursuits and contains many farm buildings and residences. Portions of the town of Everson as well as the entire town of Nooksack and Sumas are also located within the flood plain.

The levee along the right bank of the Nooksack River near Everson has reduced the recurrence frequency of overflow into the Sumas to once in 5 years, corresponding to a flow of 35,000 cfs at Deming. On a local basis, the restricted channels of the Sumas River and Johnson Creek add to the minor but frequent flooding problem. These conditions limit the use of the flood plain to a level of agriculture which can be carried out in consonance with the periodic flooding. Although major flooding can only be prevented by control of the Nooksack overflow, channel improvement along the Sumas River and Johnson Creek can significantly reduce flooding from local conditions.

### Flood Control Needs

The 5,000-acre flood plain of the United States portion of the Sumas Basin needs increased flood protection for existing developments. Average annual damages can be expected to increase in proportion to the increase in economic activity if additional protection and flood plain regulation are not provided. The trend of development is expected to result in future growths of flood damages approximating 2½ percent compounded annually which would result in future growth of annual damages to $107,000 in 1980, $176,000 in 2000, and $288,000 in 2020.

Prevention of overflow from the Nooksack River to the Sumas Basin is the most pressing need. The town of Sumas and prime agricultural lands are flooded when there is substantial overflow. Channel improvement along the Sumas River, Johnson Creek and their tributaries is needed to eliminate flooding from local conditions.

## MEANS TO SATISFY NEEDS

### Flood Control Objectives

The flood control objectives are to meet the needs set forth in the preceding section by providing flood control through utilization of both structural and nonstructural measures. Objectives of structural measures are to provide 25-year protection to agricultural lands and 100-year protection to the town of Sumas. Nonstructural measures would include flood plain management and regulation.

### Opportunities for Structural Measures

**General**—Overflow from the Nooksack River to the Sumas River drainage must be controlled before flood protection to the Sumas River flood plain can be provided. Moderate flood protection measures are then possible but long range or extensive measures would be dependent upon coordination with Canadian authorities.

**Upstream Storage**—Upstream flood control storage is economically infeasible on these small streams.

**Levees and Channelization**—The Sumas River, Johnson Creek, Squaw Creek, and the lower reaches of Dale and Breckenridge Creeks could be improved by channel improvements. These proposed improvements are discussed in Appendix XIV, Watershed Management.

### Solutions to Flood Control Needs

**General**—Features of the flood control plan are detailed in Table 3-17. Flood plain management and levee improvements are the nucleus of this plan. The flood control plan would provide for the desired development and protection through the year 2020.

**Sequence of Development**

**To 1980**—Overflow from the Nooksack River to the Sumas River Basin could be prevented by flood control storage in the proposed Edfro Dam and by levee construction along the Nooksack River. The

**TABLE 3-17. Flood control plan**

| Flood Control Feature | Sequence of Development 1980 | 2000 | 2020 | Est. Develop. Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|
| Levee Improvements | | | | |
| Levee to protect the town of Sumas–3 miles | | X | | $1,500,000 |
| Flood Plain Management | X | X | X | 1,000 |
| | | Total Cost of Plan | | $1,501,000 |

Sumas River and Johnson Creek channels should be improved by levee and channel improvements. Flood plain zoning compatible with the zoning established for the Nooksack River and with the protection provided by flood preventive improvements in the Sumas Basin should be implemented.

**1980-2000**–A ring levee to protect the town of Sumas against flooding from the Sumas River should be provided. Coordination of Canadian and United States flood control programs and objectives would be required. Channel improvements on Squaw, Dale, and Breckenridge Creeks should be accomplished during this period and are described in Appendix XIV, Watershed Management. The flood plain would be managed consistent with the protection provided.

**2000-2020**–By this period, it is expected that demand for more intensive use of flood plain lands may occur. Levee and channel improvements should be constructed to provide additional protection as required if this land use change occurs. The flood plain would be managed consistent with the protection provided.

**Accomplishments**–Implementation of the flood control plan would permit increased agricultural production on the 5,000-acre flood plain of the Sumas River and its tributaries. The town of Sumas would be provided a 100-year level of flood protection.

**Alternatives Considered**–Upstream storage was considered as an alternative flood control measure; however, the cost of providing this storage was not economically feasible.

Floodproofing of existing buildings was evaluated as an alternative to major flood protective works for reduction of present flood damages. Buildings in the town of Sumas as well as numerous rural residences and associated buildings are located in the flood plain and would require floodproofing. A high percentage of these buildings are of wood frame construction and would require structural treatment to withstand inundation by floods. This alternative was determined to be economically infeasible.

## Summary

The flood plain of the Sumas River is subject to flooding by overflow from the Nooksack River. The average annual flood damages based on 1966 prices and conditions are estimated to be $76,000 and is included with the $853,000 indicated for the Nooksack Basin. The flood plain is used primarily for agricultural pursuits and contains many farm buildings and residences. Portions of the town of Everson as well as the entire towns of Nooksack and Sumas are located within the flood plain.

Anticipated growth in the flood plain indicates that future average annual flood damages will increase to $107,000 in 1980, $176,000 in 2000, and $288,000 in 2020 if additional protection is not provided. Implementation of the Nooksack Basin flood control plan would prevent overflow of the Nooksack River into the Sumas River and provide 100-year protection to the towns of Everson and Nooksack. Implementation of the Sumas Basin flood control plan would allow increased agricultural production and provide a 100-year level of flood protection to the town of Sumas.

# Skagit-Samish Basins

# SKAGIT — SAMISH BASINS

## DESCRIPTION OF BASINS

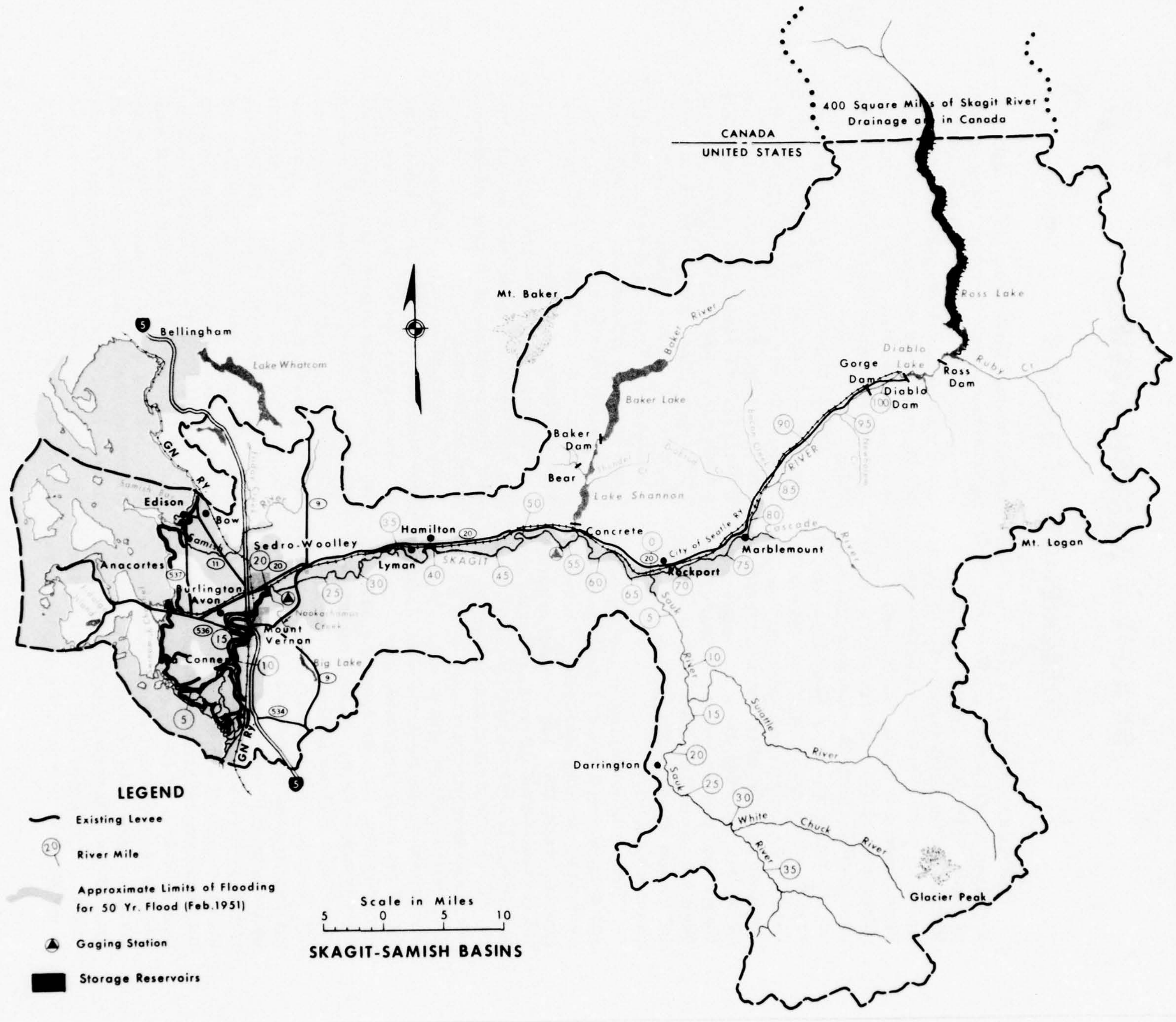
The Skagit and Samish River Basins cover about 3044 square miles in northwestern Washington. They are largely within Skagit County, but extend into Whatcom and Snohomish Counties. The basins, Figure 4-1, are bounded on the north by the Nooksack-Sumas Basins and Canada, on the south by the Stillaguamish and Snohomish Basins, on the east by the crest of the Cascade Mountain Range, and on the west by Samish, Padilla and Skagit Bays, arms of Puget Sound. The eastern part of the basin is heavily timbered, extremely rugged, mountainous terrain. Elevations vary from 10,750 feet at the summit of Glacier Peak and 9,080 feet at the summit of Mt. Logan to sea level. The principal tributaries of the Skagit River are the Sauk, Baker and Cascade Rivers, and Thunder Creek. Profiles of these streams are shown on Figure 4-2.

Soils of the mountainous areas in the eastern part of the watershed consist of shallow mantles of loams, stony and rocky loams overlying bedrock of limestone, basalt, slate, shale, schist, gneiss, granite and quartzite. Soils of the western part of the basin were formed in cemented sandy glacial till, glacial clay till and outwash glacial sands and gravels. Their textures are loams, clay loams, sandy loams, gravelly sandy loams, sands and gravelly sands. The flood plains consist of sands and gravelly sands in the upper reaches and become progressively finer textured to fine sandy loams, silt loams, loams, clay loams and silty clay loams in the lower reaches. Peats and mucks occur in many small drainage basins.

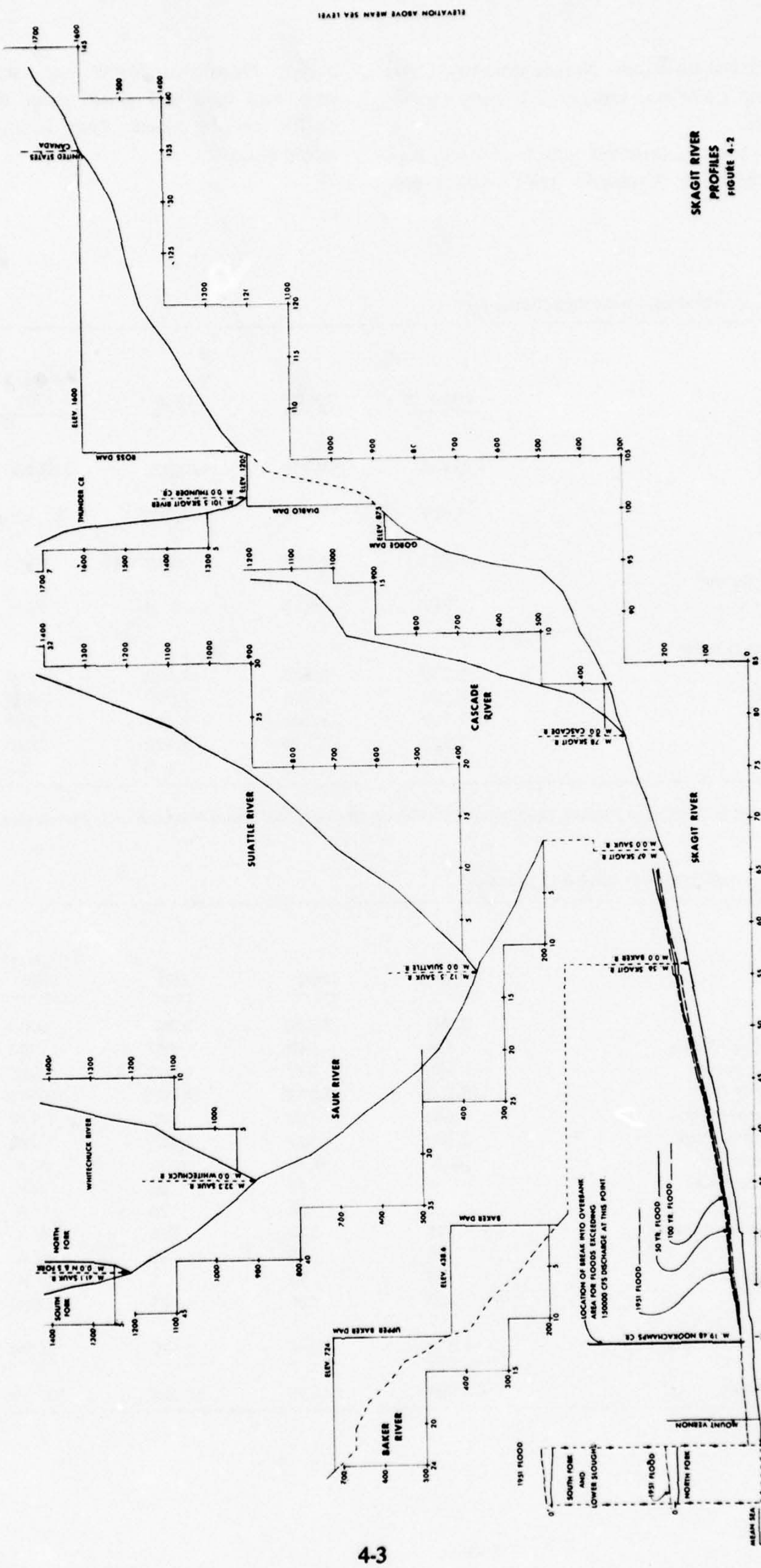
Maritime air masses and the extreme ranges in elevation cause marked differences in temperature and precipitation. In the principal agricultural portion of the basin west of Sedro Wolley, the climate is mild, without extremes of heat or cold. The extremes in temperature recorded in or near the basin have varied from a maximum of 109 F. at Diablo Dam to a minimum of -11 F at the Darrington Ranger Station and Mount Baker Lodge. The growing season varies from 105 days at Mount Baker Lodge to 236 days at Anacortes. Approximately 75% of the precipitation in the Skagit River Basin falls during the period October through March. Heavy winter snow in the higher elevations remains until late spring or early summer. The average annual snowfall varies from 504 inches at Mount Baker Lodge to 5 inches at Anacortes. The total annual precipitation varies from 109 inches at Mount Baker Lodge to 27 inches at Anacortes, but averages about 45 inches at Sedro Wolley.

Although Skagit Basin has grown steadily over past years, the pace has been slower than that of counties in the central part of Puget Sound. Population trends for the Basin and its cities and towns are shown in Table 4-1. The basin as a whole increased its population from about 38,000 in 1940 to 58,000 in 1967, a gain of 53.0 percent. The largest city is Anacortes with a current population of 8,750. It is located on an island, well out of the flood plain. The second largest city is Mount Vernon (8,402) which serves as a trade center for much of the valley farming community. It also serves the valley as a processing center for locally grown produce.

The Skagit Basin has a diversified economic base made up of agriculture, forest products, fisheries, food processing, oil refining and chemical industries. The largest farming area is west of Sedro Wolley, with 68,000 acres of rich delta lands in the flood plain. East of Sedro Woolley, farmlands are scattered along a narrow valley bottom of the upper river. Forest resources provide logs that are trucked to pulp and lumber mills in Anacortes, Everett, and Bellingham. Large migratory runs of salmon and steelhead provide a significant sport and commercial fishery resource. Plants in LaConner and Anacortes process commercial catches of fish taken near the mouth of the Skagit River and from Puget Sound and offshore waters. Employment by industry sectors is shown in Table 4-2 for 1940 through 1967. Employment in manufacturing has almost doubled since 1940, reflecting growing interest in the water-oriented locations available in north Puget Sound Counties. Employment in agriculture has declined very slightly; probably, reflecting improvement in technical efficiency since income from all farm




SKAGIT-SAMISH BASINS




SKAGIT RIVER
PROFILES
FIGURE 4-2

products sold has increased. Non-commodity industries, including trade and services, currently employ almost 10,000.

Water-transport oriented industries depend on the port facilities at Anacortes, which has a deep harbor. Petroleum, forest and fish products, chemicals, and sand and gravel move through this Port. Traffic on the Skagit River is mainly confined to rafted logs.

**TABLE 4-1. Population—past and present**

| Area | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| United States (thousands) | 132,164 | 151,326 | 179,323 | 200,100 | 52 |
| Puget Sound (thousands) | 1,007 | 1,418 | 1,768 | 2,100 | 105 |
| North Division (thousands) | 107.3 | 124.3 | 144.2 | 156.2 | 46 |
| Skagit-Samish Basins (thousands) | 37.7 | 43.3 | 51.4 | 56.9 | 51 |
| Cities & Towns in Basin | | | | | |
| Anacortes | 5,880 | 6,920 | 8,410 | 8,750 | 49 |
| Mount Vernon | 4,280 | 5,230 | 7,920 | 8,400 | 96 |
| Sedro Woolley | 2,950 | 3,300 | 3,700 | 3,850 | 31 |
| Burlington | 1,632 | 2,350 | 2,970 | 3,080 | 89 |
| Concrete | 859 | 760 | 840 | 700 | -- |

Figures are from U.S. Census Report, Seattle Area Industrial Council, 1967, and Appendix IV, Economics.

**TABLE 4-2. Employment—past and present**

| Industry | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| Agriculture | 2,691 | 2,389 | 2,000 | 2,000 | -26 |
| Forestry, Fishing, Mining | 274 | 289 | 182 | 300 | 10 |
| Contract Construction | 488 | 972 | 1,360 | 1,020 | 109 |
| Manufacturing Total | (3,133) | (3,213) | (4,307) | (6,060) | 93 |
| Food & Kindred Prod. | 448 | 669 | 743 | 1,770 | --- |
| Lumber, Wood & Furn. | 2,184 | 1,777 | 1,581 | 1,430 | --- |
| Paper & Allied Prod. | N.A. | N.A. | N.A. | N.A. | --- |
| Chem. & Allied Prod. | 4 | 18 | 36 | N.A. | --- |
| Fabricated Metal | 5 | 20 | 20 | N.A. | --- |
| Mach. (Elect & Non Elect) | 31 | 176 | 358 | N.A. | --- |
| Trans. Equip. | 10 | 42 | 92 | N.A. | --- |
| Primary Metals | 118 | 15 | 16 | N.A. | --- |
| All Other | 333 | 496 | 1,461 | 2,860 | |
| Non-Commodity Industry | 4,813 | 6,936 | 9,420 | 9,700 | 102 |
| Total Employment | 11,399 | 13,799 | 17,269 | 19,080 | 67 |

# SKAGIT AND SAMISH RIVER BASINS

## PRESENT STATUS

### Stream System

The Skagit River rises in Canada, flows southwesterly about 163 miles to Skagit Bay, an arm of Puget Sound, and drains 3,105 square miles, including 400 square miles in Canada. The Skagit is the largest river in the Puget Sound Area. About 10 miles above the mouth, the river divides and discharges through two distributaries, the North and South Forks. These forks are almost equal in length, but about 60% of the normal flow is carried by the North Fork and 40% by the South Fork. The major tributaries are the Cascade, Sauk and Baker Rivers, which join the Skagit at the towns of Marblemount, Rockport and Concrete, respectively.

The Samish River and its principal tributary, Friday Creek, originate in low mountains south of Bellingham and discharge into Samish Bay at Edison.

Table 4-3 shows the drainage areas and average annual discharges of the principal Basin streams.

**TABLE 4-3. Drainage areas and average annual runoffs**

| Stream | Drainage Area (square miles) | Average Annual Runoff (acre-feet) |
|---|---|---|
| Skagit River | 3,105 | 11,800,000 |
| Baker River | 298 | 1,870,000 |
| Sauk River | 732 | 3,180,000 |
| Samish River | 106 | 193,000 |

### Flood Plain

The flood plain includes the entire floor of the Skagit River Valley, the deltas of the Samish and Skagit Rivers, and reclaimed tidelands. The 90,000-acre flood plain contains 68,000 acres of land in the delta downstream from Sedro Woolley and 22,000 acres upstream from this city. The valley upstream from Sedro Woolley is narrow and relatively undeveloped, although farmsteads are scattered along the flood plain to Concrete. In this reach, about two-thirds of the bottom land is uncleared or occupied by river channels and sloughs. The valley bottom is characterized by flat benches that are heavily covered with bush and sharply defined by steep canyon walls. Much of the area is unsuitable for farming because of the sandy, rocky soil and the changeable river channel in the steeper sections. The valley varies in width from less than one mile along the tributaries and upper reaches of the main stem to about 2 miles at Sedro Woolley, then opens onto a broad delta outwash plain more than 15 miles wide. (See Photos 4-1, 4-2, and 4-3). The delta extends west through Mount Vernon to LaConner, and south to the flood plain of the Stillaguamish River

Developments in the flood plain include all or portions of the towns of LaConner, Conway, Mount Vernon, Burlington, Sedro Woolley, Hamilton, Rockport and Marblemount. Major industries are largely based on agriculture, except for cement production at Concrete, logging near Rockport and Marblemount, and manufacturing at Sedro Woolley.

Two major railroads cross the flood plain. The main line of the Great Northern Railway between Seattle, Washington and Vancouver, British Columbia, passes through Mount Vernon and Burlington. From Burlington, Great Northern branch lines extend westward to Anacortes and eastward to Concrete. The Northern Pacific Railway line between Seattle, Washington, and Vancouver, British Columbia, passes through Sedro Woolley.

Interstate Highway 5 and U.S. Highway 99 cross the flood plain in a north-and-south direction, paralleling the Great Northern Railway. Paved State and county highways, and numerous gravel and improved dirt roads, provide access to other parts of the basin.

Within the Skagit Basin are five airfields, three of which are small private fields near Sedro Woolley and Mount Vernon. A municipally-owned and operated airfield at Concrete and a County-owned field near Mount Vernon are being improved.

The city of Anacortes owns and operates a water supply treatment plant along the Skagit River approximately one mile upstream from Mount Vernon. The plant has a capacity of 25 million gallons per day.

### History of Flooding

**Flood Characteristics.** High water is experienced each year during the spring or early summer when rising temperatures melt the accumulated snowpack; however, the rise is relatively slow and of long duration, and has never reached a major damage stage. Major floods are caused by a series of rain storms that move across the basin from the Pacific Ocean during the winter. Floodflows may have two

PHOTO 4-1. Sedro Woolley, in the foreground, is on the low divide between the Skagit River on the left and Samish River on the right, and is subject to flooding.

PHOTO 4-2. View of flood plain looking northeasterly with LaConner and Swinomish Channel in the foreground. The North Fork of the Skagit River is at the extreme right.

PHOTO 4-3. View of delta looking southwesterly. Mount Vernon and the Skagit River are in the foreground. The Strait of Juan de Fuca is in the extreme background.

or more crests within a period of two weeks, and are characterized by sharp increases with a recession almost as rapid, and cause heavy damages.

Streamflow recorded at the Concrete gage is representative of the Skagit River and its major tributaries. This gage measures the runoff from 2,737 square miles, or 88% of the basin. The runoff pattern is indicated in Figure 4-3 and shows that the average monthly discharge is the largest during the spring. The daily discharge is illustrated in Figure 4-4. Instantaneous discharges have varied from less than 4,000 cfs to a peak in excess of 300,000 cfs.

Figure 4-5 shows the runoff pattern for the Sauk River and depicts the similarity with streamflow in the main river.

**Floods.** Discharges on the Skagit River have been recorded intermittently since October 1908. Gaging stations were installed near Concrete in December 1924, near Sedro Woolley in 1908, and near Mount Vernon in October 1940. Known and estimated peak discharges above 60,000 cfs at the gage near Concrete are listed in Table 4-4. The U.S. Geological Survey estimated peak discharges at the gage near Concrete for the years prior to 1924. Storage at the following hydropower installations has partially regulated flows: Lake Shannon on the Baker River since 1926, and Diablo Reservoir since 1930 and Ross Reservoir since 1940 on the upper Skagit River. Since 1953, 120,000 acre-feet of flood control storage in Ross Reservoir has reduced peak discharges. Except for Ross Reservoir, existing storage has no significant effect on flooding.

Zero damage flow on the Skagit River is considered to be 60,000 cfs at Concrete. Since 1924, this flow has been exceeded at least 29 times. Table 4-5 summarizes the peak flows and recurrence intervals for four of the largest floods since 1908 and estimated damages at 1966 prices and conditions. Probability curves referenced to the gaging stations near Concrete, Sedro Woolley and Mount Vernon are shown in Figures 4-6, 4-7 and 4-8.

The November 1909 flood had a peak discharge of 260,000 cfs at Concrete and 200,000 cfs at Sedro Woolley, and was the largest flood since the inception of records in 1909. This flood breached the dike near Burlington and flooded most of the land between Burlington and the Swinomish Channel. Photo 4-4 shows the flooded area in the vicinity of Mount Vernon. The Burlington dike is subject to overtopping when flood discharges exceed 150,000 cfs. When this dike is overtopped or fails, floodwaters

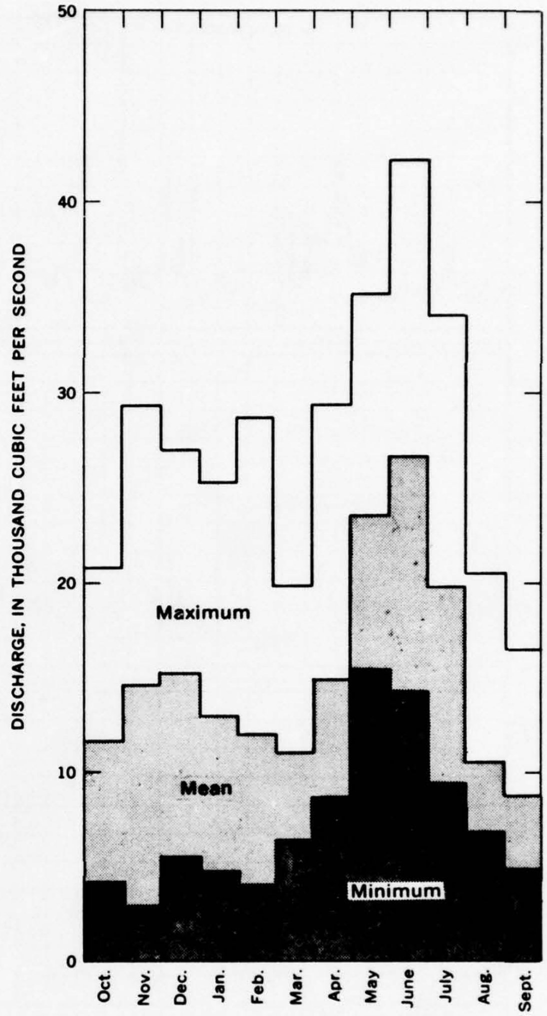



FIGURE 4-3. Maximum, mean and minimum monthly discharges, Skagit River near Concrete, 1931-1960.

overflow the low divide which separates the Samish and Skagit Basins.

The December 1921 flood crested at 240,000 cfs near Concrete, but dropped to 210,000 cfs at Sedro Woolley and 150,000 cfs at Mount Vernon. The decrease in discharge as the flood advanced downstream resulted from natural valley storage upstream from Sedro Woolley. Downstream from Sedro Woolley, a break in the dikes just above the Great Northern Railroad bridge between Burlington and Mount Vernon permitted an extimated 60,000

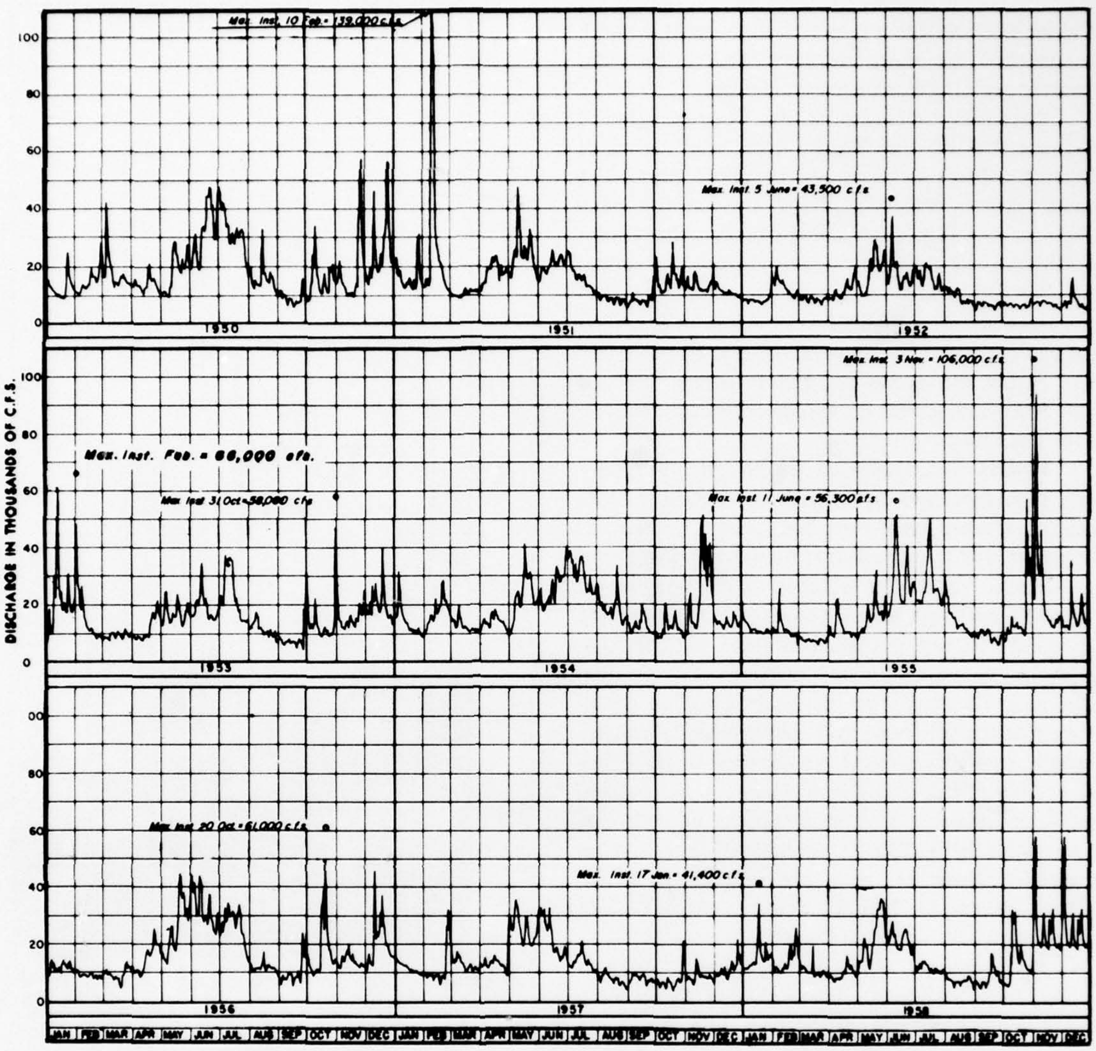



**FIGURE 4-4. Daily discharge hydrograph, Skagit River near Concrete.**

cfs to enter the Samish River delta and the area between Bayview and Pleasant Ridge.

The February 1951 flood had a peak discharge of 139,000 cfs at Concrete, 150,000 cfs at Sedro Woolley, and 144,000 cfs at Mount Vernon. The flood remained near its peak for six hours at Mount Vernon, contributing significantly to the severity of flood damages. Natural storage in the Nookachamps Creek area between Sedro Woolley and Mount Vernon was completely utilized, and dikes failed because they lacked sufficient cross-sectional dimensions to withstand saturation. (See Photo 4-5).

**Flood Damages.** Basic data for estimates of flood damages in the valley west of Sedro Woolley were obtained by field appraisals in 1940, 1950 and 1961. In 1967, a preliminary appraisal was made of flood damages for the valley east of Sedro Woolley. In Table 4-5, the estimated damages at 1966 prices and conditions are shown for floods that occurred in November 1909, December 1921, November 1949, and February 1951. The average annual damage in the Skagit flood plain downstream from Marblemount was found to be $3,020,000 at 1966 prices and conditions.

In the delta, the breaching of tidal dikes by impounded floodwater presents special problems because salt water intrusion may reduce the productivity of farmlands from one to ten years. Flood flows

**TABLE 4-4. Peak discharges, Skagit River**

| Date | Skagit River near Concrete |
|---|---|
| About 1815 | 500,000 |
| about 1856 | 350,000 |
| 19 Nov. 1897 | 275,000 |
| 30 Nov. 1909 | 260,000 |
| 30 Dec. 1917 | 220,000 |
| 13 Dec. 1921 | 240,000 |
| 12 Dec. 1924 | 92,500 |
| 16 Oct. 1926 | 88,900 |
| 12 Jan. 1928 | 95,500 |
| 9 Oct. 1928 | 74,300 |
| 26 June 1931 | 60,600 |
| 27 Feb. 1932 | 147,000 |
| 13 Nov. 1932 | 116,000 |
| 22 Dec. 1933 | 101,000 |
| 25 Jan. 1935 | 131,000 |
| 3 June 1936 | 60,000 |
| 19 June 1937 | 68,300 |
| 28 Oct. 1937 | 89,600 |
| 29 May 1939 | 79,600 |
| 2 Dec. 1941 | 76,300 |
| 3 Dec. 1943 | 65,200 |
| 8 Feb. 1945 | 70,800 |
| 25 Oct. 1945 | 102,000 |
| 25 Oct. 1946 | 82,200 |
| 19 Oct. 1947 | 95,200 |
| 27-28 Nov. 1949 | 154,000 |
| 10-11 Feb. 1951 | 139,000 |
| 1 Feb. 1953 | 66,000 |
| 3-4 Nov. 1955 | 106,000 |
| 20 Oct. 1956 | 61,000 |
| 30 April 1959 | 90,700 |
| 23-24 Nov. 1959 | 89,300 |
| 16 Jan. 1961 | 79,000 |
| 20 Nov. 1962 | 114,000 |
| 22 Oct. 1963 | 73,800 |

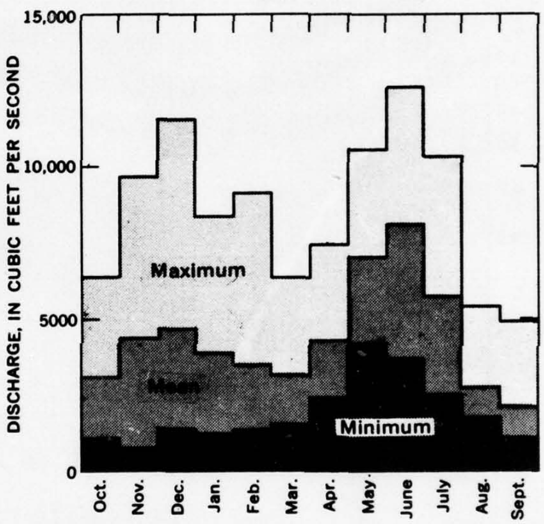



FIGURE 4-5. Maximum, mean and minimum monthly discharges, Sauk River near Sauk, 1931-1960.

**TABLE 4-5. Major floods and estimated damages**

| Date | Peak Discharge at Concrete (cfs) | Average Recurrence Interval (years) | Current Estimated Damages |
|---|---|---|---|
| 30 Nov 1909 | 260,000 | 100 | $22,170,000 |
| 13 Dec 1921 | 240,000 | 81 | 20,820,000 |
| 27 Nov 1949 | 154,000 | 14 | 9,090,000 |
| 10 Feb 1951 | 139,000 | 10 | 16,650,000 |

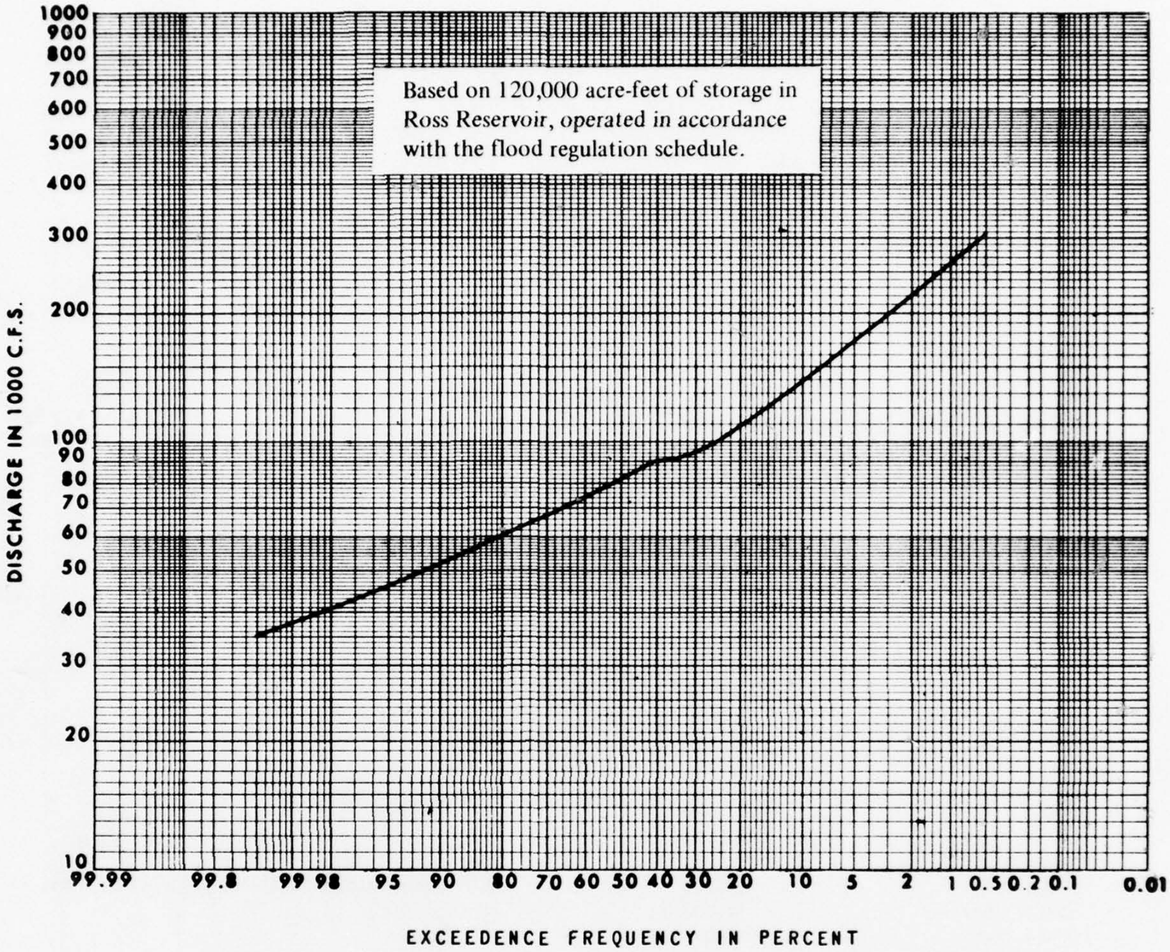



**FIGURE 4-6. Frequency curve of annual maximum peak flows, Skagit River near Concrete**

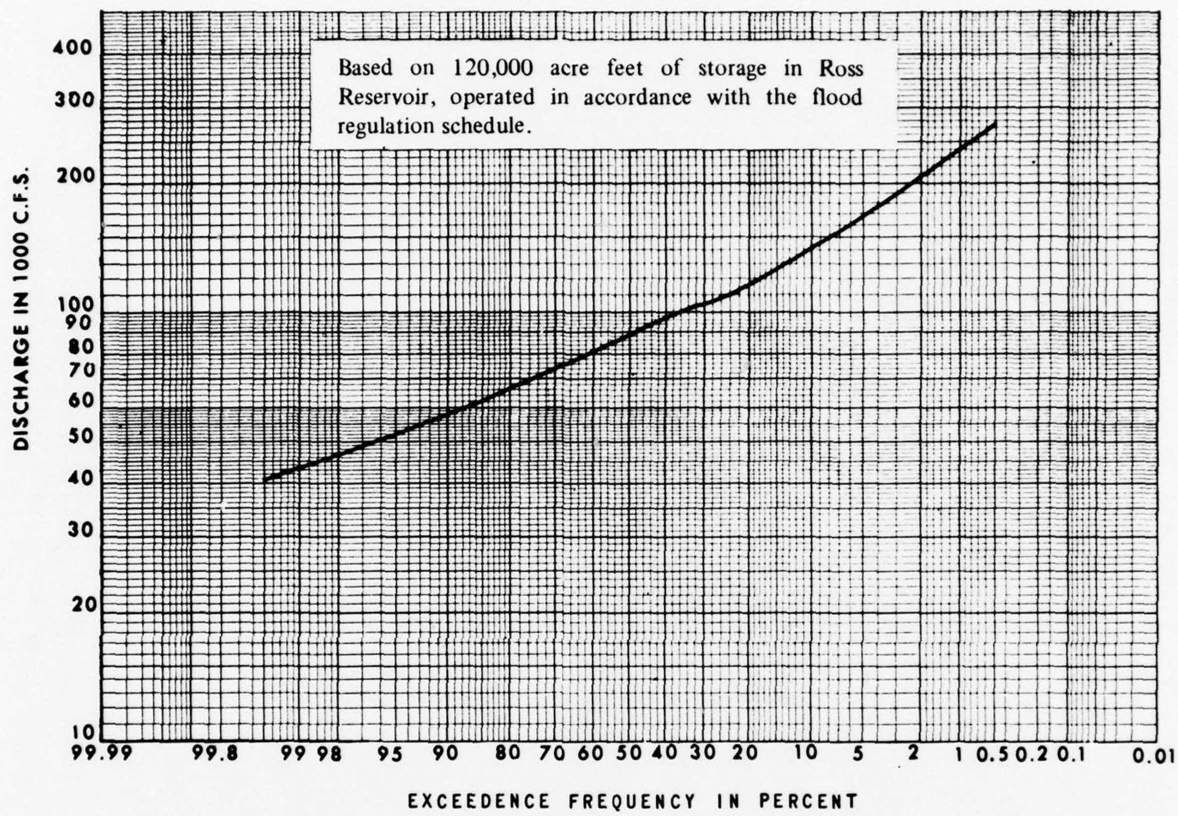



**FIGURE 4-7. Frequency curve of annual maximum peak flows, Skagit River near Sedro Woolley**

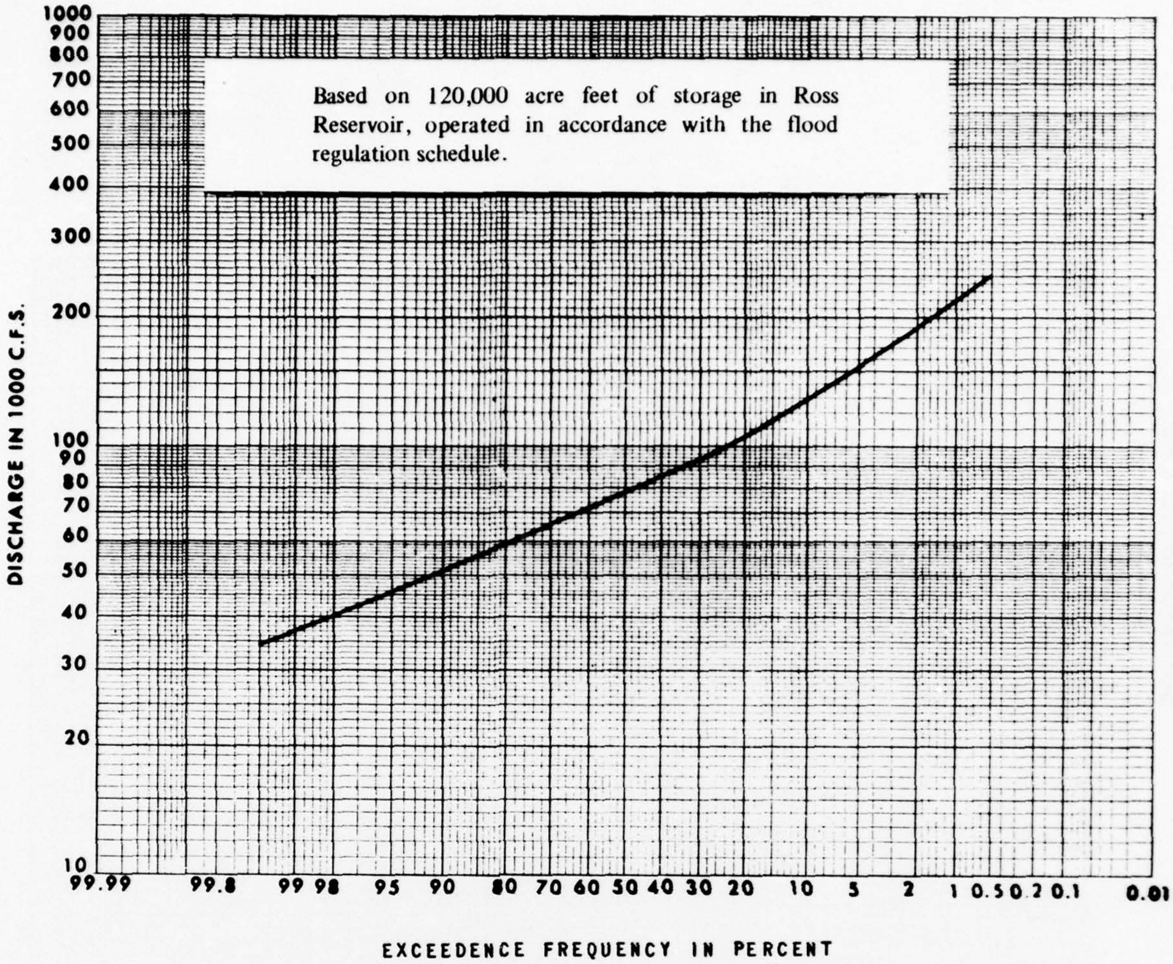



**FIGURE 4-8. Frequency curve of annual maximum peak flows, Skagit River near Mount Vernon**

PHOTO 4-4. November 1909 flood view of flooded area west of Mt. Vernon on the right bank of the Skagit River (Courtesy of Mrs. Stevenson).

erode the riverbanks, and severely damage buildings in urban communities, farmland and farm buildings, utilities, levees and roads in the lower reaches.

Table 4-6 gives the flood damages by general damage categories as described in the Puget Sound Area section of this appendix, and shows the percentage of total damage that would result from major flood discharges.

**TABLE 4-6. Flood damage distribution—Skagit River**

| Category | Percent of Total Damage |
|---|---|
| Agriculture | 57 |
| Buildings and equipment | 36 |
| Other | 7 |
| | 100 |

The impact of progressive stages of flooding on highways, lands and communities is shown in Figure 4-9.

## Existing Flood Control Measures

**Flood Forecasting and Warning.** Flood forecasting service is provided by the U.S. Weather Bureau. When the gage on the Skagit River near Mount Vernon indicates that the flow will exceed the zero damage stage, the Weather Bureau issues a flood warning, as described in the Puget Sound Area Section of this appendix. The Skagit County Civil Defense Organization is developing an emergency flood warning plan, which includes the receipt of warnings by radio and dissemination by means of stationary and mobile sirens.

The interval between rainfall and crest in the vicinity of Mount Vernon is 24 hours. The Skagit County Engineer determines the county's flood fighting capability and the appropriate time to require evacuation or request Federal assistance.

**Flood Protective Works.** Flood control works on the Skagit River include levees, bank protective and stabilization works, and upstream storage.

**Levees.** The levees and sea dikes shown on Figure 4-1 were constructed by 16 diking districts

PHOTO 4-5. Flooding of farmlands is a common occurrence in the flood plain, as illustrated by this photo taken during the 1951 flood in the Freshwater Slough area (Corps of Engineers Photo).

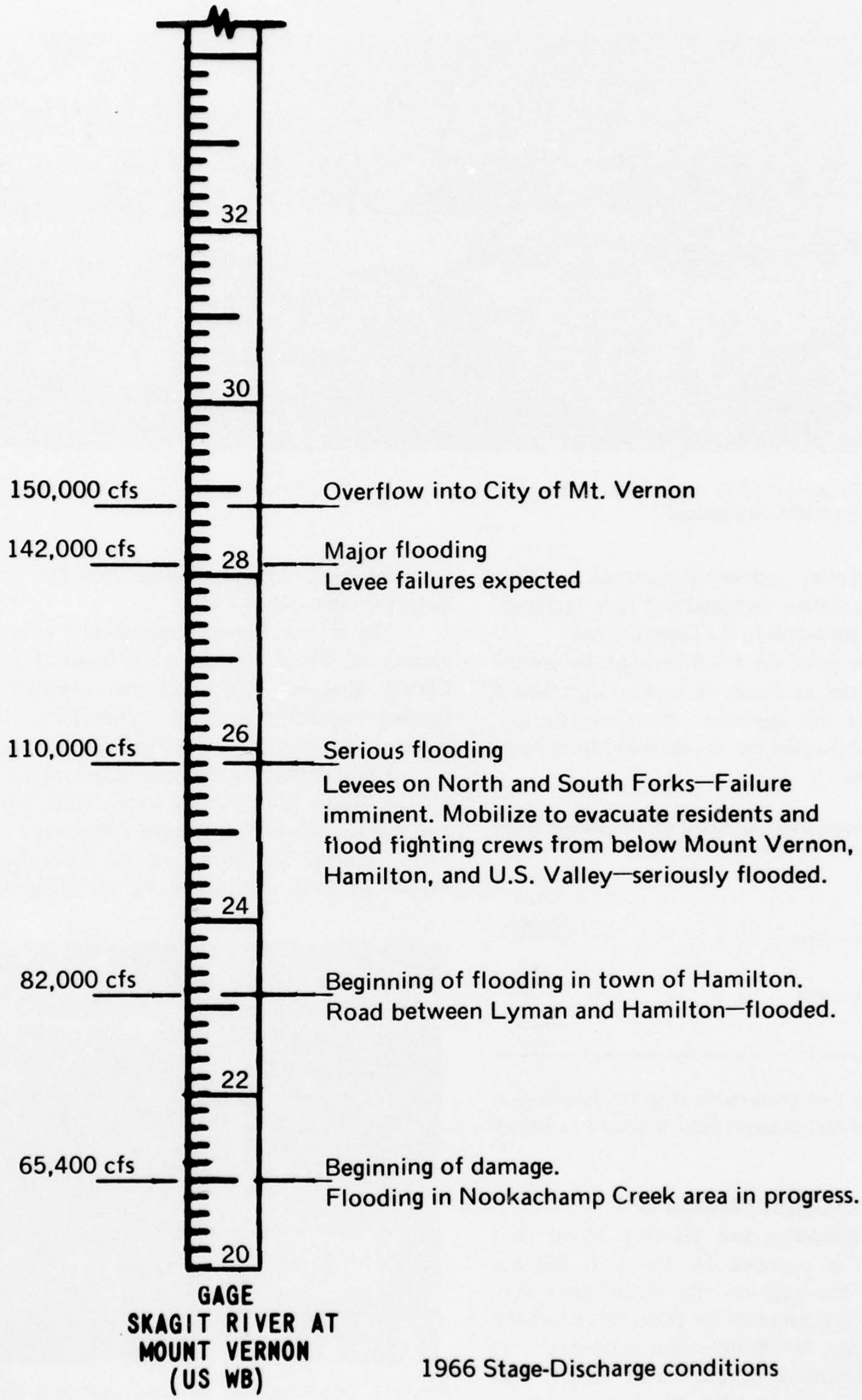



**FIGURE 4-9. Progressive stages of flooding, Skagit River**

and a few private individuals. The diking districts maintain 55.8 miles of levees and 39 miles of sea dikes to protect 45,000 acres of land. Individual owners maintain 16 miles of levees to protect 1,000 acres. The level of protection afforded by diking district levees is summarized in Table 4-7.

**TABLE 4-7. Protection by diking district levees**

| Location | Miles of Levee | Protection: To Flow (cfs) | Protection: Recurrence Interval (years) |
|---|---|---|---|
| **Skagit River** | | | |
| Right bank–Burlington to the mouth of the North Fork (River Mile 2-21) | 16.1 | 108,000 | 5 |
| Left bank–Burlington to Mt. Vernon (River Mile 21 to 13) | 7.5 | 143,000 | 14 |
| Left bank–Mt. Vernon to mouth of the South Fork (River Mile 13 to 2) | 14.4 | 101,000 | 4 |
| Left bank of the North Fork | 5.5 | 91,000 | 3 |
| Right bank of the South Fork | 6.0 | 91,000 | 3 |
| **Samish River** | | | |
| Right bank | 4.3 | 123,000 | 8 |
| Left bank | 2.0 | 123,000 | 8 |
| TOTAL | *55.8 miles* | | |

Overtopping of low areas in the levee system begins at flows of 84,000 cfs. By sandbagging and minor flood fighting, the levees have held against a 91,000 cfs flow (Mount Vernon Gage). The entire city of Burlington relies on levees for flood protection. Conway, West Mount Vernon, the central business district of Mount Vernon, and residential areas to the south are also protected by levees. LaConner is protected from high tides by the sea dike along the Swinomish Channel. Interior dikes prevent Skagit River overflows from reaching the city.

**Bank Protection.** With financial aid from the Agricultural Stabilization and Conservation Service and the State of Washington, property owners and Skagit County constructed extensive bank stabilization works along the river in an effort to reduce land losses caused by erosion. For the most part, these projects consisted of rock revetments. Pile and plank walls and other means were also used with varying results. In recent years, most of the bank protective work has been done by the diking districts with the help of county, State and Federal agencies to prevent erosion and the undermining of levees. In 1938, the Works Progress Administration completed the construction of bank protective facilities upstream from Sedro Woolley. The work included channel clearing and protecting the riverbanks with brushmat bundles staked to freshly sloped banks. Most of the W.P.A. works have deteriorated.

Since 1947, the Corps of Engineers has assisted in the reconstruction of flood damaged levees and has provided additional bank protection where public utilities, such as roads and bridges, were endangered or where riprap was necessary to protect levee repairs. This work has been performed at a Federal cost of $373,300.

**Upstream Storage.** The city of Seattle owns and operates a system of three hydroelectric powerplants on the upper Skagit River at Gorge, Diablo and Ross Dams. The Gorge and Diablo reservoirs are used only for power generation. Ross reservoir has 1,052,1[illegible] acre-feet of usable storage between elevations 1,60[illegible] and 1,475 feet, of which 120,000 acre-feet are reserved for flood control in compliance with the Federal Power Commission license. Flood storage is used only when the discharge at Concrete is forecast to be 90,000 cfs or greater. The effectiveness of storage in reducing peak discharges depends upon the location of the storm center and other variable storm characteristics. Under average conditions, Ross Dam reduces flood crests by 15,000 to 25,000 cfs at Sedro Woolley.

The Puget Sound Power and Light Company operates two hydroelectric powerplants on the Baker River. The Upper Baker Reservoir provides 16,000 acre-feet of flood storage to compensate for natural channel storage lost by construction of the dam. Flows are regulated to avoid increasing flood heights above natural conditions, but neither the Upper nor Lower Baker Reservoirs contribute significantly to flood control. The Federal Power Commission license for the Upper Baker Dam requires that an additional 84,000 acre-feet of storage for flood control may be requested by the Corps of Engineers provided that suitable arrangements are made for compensating

Puget Sound Power and Light Company for power losses incurred. The Lone Star Cement Corporation also operates two small powerplants on Bear Creek, a tributary of the Baker River. These plants produce a small amount of power and have no significant storage capacity.

**Flood Plain Management.** The Corps of Engineers has issued a report, "Flood Plain Information Study, Skagit River Basin, Washington (April 1967)," which provides information on problems associated with flood plain development. Suggestions are made on how flood hazards can be minimized or prevented. Skagit County is in the process of issuing ordinances that will establish a floodway that can accommodate a 15-year-frequency flood, and fringe zones wherein development will be controlled by special building and health regulations. Further information on flood plain management is given in the Puget Sound Area section of this appendix.

**Authorized Flood Control Projects.**

**Diversion Channel.** The Avon Bypass project was authorized by the Flood Control Act of 1936 and was reactivated in 1960. This project would divert about 60,000 cfs of Skagit River floodwaters from near Burlington to Padilla Bay and increase flood protection for the 68,000 acre delta downstream from Sedro Woolley and the towns of Burlington, Mount Vernon, Conway and LaConner.

**Levee and Channel Improvements.** The Flood Control Act of 1966 authorized strengthening existing levees and minor channel improvements along the lower 17 miles of the Skagit River. This project would increase the present maximum channel capacity from 91,000 cfs to about 120,000 cfs.

The authorized levee and channel improvements together with the authorized Avon Bypass would have a combined channel capacity of 180,000 cfs and would increase the minimum level of protection downstream from Sedro Woolley from 3 to 35 years.

## Flood Problems

**Skagit River.** In the 68,000 acres west of Sedro Woolley, extensive agricultural and urban developments are exposed to excessive flood hazards because the capacity of the river channel is insufficient to carry major flood flows. Existing levees in combination with available upstream storage provide protection against flows with a recurrence interval of once in 3 to 15 years. Poor foundation conditions preclude raising the existing levees.

The levees along the right bank in the vicinity of Burlington are subject to overtopping when flood discharges exceed 150,000 cfs on the Mount Vernon gage, or a flow with an expected recurrence interval of about once in 20 years. Levee failures allow floodflows to pass through Burlington and into the Samish Basin.

East of Sedro Woolley, minor flooding begins at about 42,000 cfs on the gage near Sedro Woolley. A county road between Lyman and Hamilton and scattered farms in this reach of valley bottom are subject to extensive flooding whenever flows exceed about 70,000 cfs on the Sedro Woolley gage, or a flow with an expected recurrence interval of once in about two years. Changes in the course of the river channel result from accelerated river bank erosion.

**Tributary Streams.** Small tributaries of the Skagit River also have overbank flood problems.

Grandy, Jones and Hansen Creeks enter the Skagit River from the north in the reach between Sedro Woolley and Concrete. These streams have a very steep gradient and abruptly level off where they join the Skagit flood plain. During periods of intense precipitation, the streams rise rapidly and deposit large amounts of sediments that form debris cones at their mouths. The course of floodwaters at these cones is unpredictable, and debris dams sometimes result. If these dams fail, the surge of impounded water carries trees and other detritus onto lower lands.

Nookachamps Creek enters the Skagit River from the south near Burlington. In addition to backwater from the Skagit River, flooding occurs almost annually within the watershed.

**Samish River.**

**Upper Samish River.** Approximately 1,200 acres in the upper Samish Basin are subject to overbank flows by both the river and its tributaries. Rainfall is heavy at the higher elevations, the streams rise rapidly and carry heavy bedloads, and the gradients are very steep. However, upon entering the Samish flood plain, the stream gradient flattens abruptly and sediment deposited at the edge of the flood plain create debris cones which increase in size year after year. Water readily infiltrates the coarse material and tends to become subsurface flow, reappearing farther down the slope as springs or wet areas. Streamflow spreads in all directions over the debris cones and may cause flooding many times during the rainy season. The Samish River occasion-

ally is blocked by the debris deposited by the tributaries, and considerable areas in the flood plain remain flooded until another channel is cut into the floor of the valley.

**Lower Samish River.** The Samish River enters the northern part of the Skagit River flood plain and winds westerly to Samish Bay. This area is subject to overbank flows from both the Skagit and Samish Rivers. The Samish overflows its banks on a frequency of once every two years. The lower reach of the Samish River has a flat gradient and the flood plain is intensively farmed. The removal of floodwater is accomplished by gravity through flap gates set at a low elevation in the levee and, in some instances, pumps. Most of the area is protected from high tides and storms by levees. The Samish River is levied on each side for several miles upstream from its mouth where high tides do not overflow the natural banks of the river. The flood plain north of Edison and Bow is protected by a levee on Samish Bay, but is often flooded by water flowing off Chuckanut Mountain and by overbank flows of the Samish River.

## PRESENT AND FUTURE NEEDS

### Evaluation of Present Situation

The 90,000-acre flood plain of the Skagit and Samish Rivers is partially protected by levees and upstream storage. Levees begin at Sedro Woolley and extend westerly to the mouth, protecting about 46,000 acres. Flood storage of 120,000 acre-feet in Ross Reservoir controls inflow from approximately 1,000 square miles of the upstream drainage area, or about one-third of the total watershed. The remaining two-thirds of the drainage area is uncontrolled and yields the major flood producing runoff. The flood plain is utilized primarily for agriculture, but also contains commercial and residential developments in the towns of LaConner, Conway, Mount Vernon, Burlington, Sedro Woolley and Hamilton.

Flood damage begins when the flow is about 60,000 cfs at Concrete. Average annual flood damages are estimated to be $3,020,000 to urban development, farmlands and farm buildings, transportation facilities, and utilities.

When flows at Concrete are forecast to reach 90,000 cfs, the discharge by Ross Dam is reduced to that required for power generation only, thereby reducing major flows at Sedro Woolley by 15,000 to 25,000 cfs. The capacity of the river channel between Concrete and Sedro Woolley is about 60,000 cfs although minor flooding does occur at lesser discharges. Flooding of the county road between Lyman and Hamilton begins at about 70,000 cfs, and in the town of Hamilton, at about 82,000 cfs on the Sedro Woolley gage.

Levees below Sedro Woolley provide protection against flows varying from 91,000 to 143,000 cfs measured at the Mount Vernon gage. This variation results from non-uniform levee heights. The foundation material on which these levees are constructed consists of silts and sands, and raising the levees is not feasible.

The level of flood protection in the lower delta is not adequate to protect existing development. Farms and urban development in the communities of Mount Vernon, Burlington, Sedro Woolley and Conway need adequate flood control.

The Avon Bypass diversion channel, together with channel and levee improvements, would increase the present minimum level of flood protection from once in three years to once in 35 years.

Isolated farms east of Sedro Woolley and the communities of Lyman and Hamilton require increased protection against flood damages.

Flooding also occurs along tributaries. Mountain streams with steep gradients carry sediments and debris during peak discharges, the capacities of the drainage channels are inadequate to carry high flows, and debris often is deposited on cultivated farmland.

### Economic Trends

The economic pattern of the Skagit-Samish River Basin is characterized by the economic growth of the North Division comprised of Whatcom, Island, San Juan, and Skagit Counties. Projections of economic growth for the North Division have been made for the years 1980, 2000, and 2020 in Appendix IV. Table 4-8 contains a forecast of population, employment, and gross regional product for the North Division and projects population for the Skagit-Samish River Basin. Table 4-9 converts these forecasts into rates of growth and compares these rates to those projected for the United States.

The North Division of the Puget Sound Area is forecast to grow at an accelerated rate to the year 2000. In the 57-year period following 1963, the projected average annual growth is 1.4 percent for population, 1.5 percent for employment, and 4.3 percent for gross regional product. The pattern of expansion is emphasized when compared to the

United States which is expected to realize rates of 1.3 percent, 1.5 percent, and 4.0 percent for the same indicators and time periods.

The Skagit-Samish Basins' potential growth industries are aluminum, primary metals, pulp and paper, and education. Employment is projected to rise, but at a lower rate than gross regional product because of greater productivity increases in the industries. Employment and gross regional product are expected to keep pace with population growth.

**TABLE 4-8. Economic projections**

| North Division | 1963 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Population (thousands) | 151.0 | 185.5 | 249.9 | 341.5 |
| Employment (thousands) | 45.5 | 57.9 | 78.2 | 106.7 |
| Gross Regional Product (millions 1963 $) | 369.0 | 848.0 | 1800.0 | 3977.0 |
| Skagit-Samish River Basin | | | | |
| Population (thousands) | 53.8 | 64.2 | 86.5 | 118.2 |

**TABLE 4-9. Average annual growth trends, (per cent)**

| | 1963 to 1980 | 1980 to 2000 | 2000 to 2020 | 1963 to 2020 |
|---|---|---|---|---|
| United States | | | | |
| Population | 1.3 | 1.3 | 1.3 | 1.3 |
| Employment | 1.6 | 1.4 | 1.3 | 1.5 |
| Gross National Product | 4.3 | 3.9 | 4.0 | 4.0 |
| North Division | | | | |
| Population | 1.2 | 1.5 | 1.6 | 1.4 |
| Employment | 1.4 | 1.5 | 1.5 | 1.5 |
| Gross Regional Product | 5.0 | 3.9 | 4.0 | 4.3 |
| Skagit-Samish River Basin | | | | |
| Population | 1.0 | 1.5 | 1.6 | 1.4 |

## Land Use Trends

The trend in land use in the flood plain is toward more intensive agriculture. Additional urban and industrial land uses can be expected to occur in the flood plain on the waterfront, along Interstate Highway 5, and at the towns of Mount Vernon, Burlington, Sedro Woolley, and Conway. Expansion of farm income depends on conversion of lands to higher value crops or to increased productivity. Future increase of farm income in the Skagit-Samish River Basin will result largely from higher yields on existing crops because of the present relatively high stage of agricultural development.

## Flood Control Needs.

**Prevention of Flood Damages.** The 90,000 acre flood plain of the Samish and Skagit Rivers requires increased flood protection for future and existing developments. Average annual damages are estimated to be $3,020,000 and the damages that could result from a flood with an estimated frequency of 100 years is estimated to be $22,170,000. Losses of this magnitude could be reduced by offering a higher level of protection and by zoning the flood plain use consistent with the higher level of protection.

Based on the methodology and considerations previously discussed for the Puget Sound Area anticipated flood damages in the flood plains of the Skagit River Basin are expected to increase by the percentages as shown in Table 4-10.

**TABLE 4-10. Percentage increase in productivity levels and developments for specified periods**

| Category of Damage | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Agriculture | 19 | 27 | 25 |
| Non-Agriculture | 60 | 100 | 100 |

Application of these percentages to the average annual damages based on 1966 prices and conditions provides an indication of future damages at 1966 prices without additional flood protection. Table 4-11 shows that the combination of all categories of damage are expected to increase from about $3,020,000 in 1966 to $12,030,000 by the year 2020.

**TABLE 4-11. Existing and future annual damages (in thousands of dollars)**

| Category | Under Development Levels of 1966 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Agriculture | 1,720 | 2,220 | 2,820 | 3,530 |
| Buildings & Equipment | 1,090 | 1,780 | 3,550 | 7,120 |
| Other | 210 | 340 | 690 | 1,380 |
| TOTAL | 3,020 | 4,340 | 7,060 | 12,030 |

There is a need to reduce the present flood damages of $3,020,000 annually that occurs to croplands, dwellings, roads and utilities in the flood plain. The trend of development within the basin would result in future growths of flood damages approximating 2½ percent compounded annually without flood control and will result in future growth of annual damages to $4,340,000 in 1980, $7,060,000 in 2000 and $12,030,000 in 2020. Commercial and urban development in the communities of Mount Vernon, Burlington and Sedro Woolley will become part of the future annual damages. Flood plain zoning regulation would be only partially successful in slowing development in the flood plain. There is a need to reduce these projected damages to allow development of the full economic potential of the Skagit-Samish River Basin.

**Optimum Flood Plain Use.**

**Agriculture.** The major portion of land in the Skagit-Samish River Basin will continue in its high stage of agricultural development to the year 2020. Farm production will have to increase on the remaining acreage to satisfy the food and fiber demands. An increase in agricultural production will require at least a 25-year level and preferably a 50-year level of flood protection to assure occupants of these lands increased farm returns.

**Recreation.** Public boat launching ramps, swimming beaches, park facilities, and scenic drives are forecast to be developed in portions of the flood plain. To permit construction and development of these recreational facilities, a level of flood protection of 10 to 15 years is required.

**Intensive Land Use.** Present intensive land use in the Skagit-Samish Basins totals about 19,000 acres with the majority of these lands located around the existing communities of Anacortes, Mount Vernon, and Sedro Woolley. Population of the basin is projected to increase from about 58,000 in 1967 to 118,200 by the year 2020 and intensive land use needs are expected to total 29,000 acres. By careful land use selection a high degree of maintenance of the present agricultural lands in the basins can be achieved.

**Summary of Flood Control Needs.** Flood control is required to facilitate intensive land use in the Skagit-Samish River Basin. Existing towns of Mount Vernon, Sedro Woolley, Burlington, and Conway require a 100-year level of flood protection. Agricultural lands need sufficient flood protection to allow for increased economic returns from the land. A lesser measure of flood control is required to protect recreational facilities. Structural measures should be provided to the maximum extent that economics will permit, and land areas should be managed to allow developments commensurate with the flood protection provided.

## MEANS TO SATISFY NEEDS

### Flood Control Objectives

The flood control objective is to satisfy the needs described in the previous section by providing flood control through utilization of both structural and non-structural measures. Objectives of structural measures are shown below in Table 4-12. Non-structural measures would include a flood plain warning system and flood plain management consistent with the flood protection provided.

**TABLE 4-12. Objectives of structural measures**

| Flood Plain Designation | Levels of Protection* 100 year | 50 year | 25 year |
|---|---|---|---|
| 68,000 acres of delta area located west of the town of Sedro Woolley | | X | |
| 22,000 acres of river bottom land east and upstream of the town of Sedro Woolley | | | X |
| Urban Areas of: | | | |
| Sedro Woolley | X | | |
| Burlington | X | | |
| Mount Vernon | X | | |
| LaConner | X | | |
| Edison | X | | |
| Hamilton | X | | |
| Lyman | X | | |

* For floods that can be expected to occur on an average of once in the period designated.

### Opportunities for Structural Measures

**Upstream Storage.** Approximately 800,000 acre-feet of additional flood control storage is required to provide a 100-year level of flood control in the basin. Sites for such storage exist on the main Skagit, Baker, Sauk, Suiattle, and Cascade Rivers. Approximately 100,000 acre-feet of storage in the upper Baker River project owned and operated by the Puget Sound Power and Light Company could be effectively utilized for flood control. Approximately

325,000 acre-feet of effective flood control storage could be provided on the Sauk River, the major tributary of the Skagit River.

**Levees and Channelization.** Construction of levee and channel improvements are effective methods of providing flood control. Major raising of the levee system along the Skagit River in the delta area is not practical due to inadequate levee foundation conditions. The excessive head resulting from the levee construction would result in failure of levee foundations. Minor raising of the low areas in the existing levee system downstream from the Burlington-Mount Vernon area in combination with channel widening of constricted reaches would develop a channel capacity of 120,000 cfs. Levee protection would be effective in controlling Skagit River floods to about 6,000 acres in the Nookachamps Creek area. Flood control by major levee construction would be effective for the protection of urban areas extending into the flood plain such as Hamilton, Lyman, Burlington, Sedro Woolley, and Mount Vernon.

**Diversion.** Diversion is a major consideration for providing flood control to the Skagit River delta and could be accomplished by construction of the authorized Avon Bypass Channel. The Avon Bypass would have an 8-mile channel with an intake from the Skagit River located about 1 mile downstream from Burlington and would extend westward to Padilla Bay.

## Constraints on Structural Measures

**Preservation.** Portions of the Skagit and Sauk Rivers and other tributaries are presently being considered for inclusion in the national wild and scenic rivers system.

**Levees.** Major ponding, particularly in the Nookachamps Creek area, results in significant reduction in downstream floodflows. Levee construction in this area could transfer flood damages downstream. Upstream storage or increased downstream channel capacity would be required to compensate for losing this natural valley storage.

## Solutions to Flood Control Needs

**General.** Features of the flood control plan are detailed in Table 4-13 and shown on Figure 4-10. The plan, consisting of levee and channel improvements, the Avon Bypass, upstream storage, and flood plain management, would provide for the desired development and protection through the year 2020.

**Sequence of Development.**

**1980.** Levee and channel improvements along the river and its distributaries downstream from the Burlington—Mount Vernon area in combination with construction of the Avon Bypass including the upstream levee extension and flood storage in Upper Baker Reservoir are the most immediate flood control needs in the basin. Protection of the Nookachamps Creek area by levee construction could also be completed during this period. Flood plain zoning and regulation should be provided commensurate with the level of flood protection provided.

**1980-2000.** Urban areas at the town of Hamilton could be provided 100-year protection by construction of a three mile levee. Urban areas in the city of Sedro Woolley could be provided a 100-year level of flood control by construction of a four mile levee. Construction of a storage project at the lower Sauk site would complete the flood control plan. Flood plain regulation should be continued.

**2000-2020.** By this period, it is expected that demand for more intensive use of flood plain lands may require increased protection in some areas. This protection could be provided by levee construction. Flood plain regulation should be continued.

**Economic Analysis for 1980 Level of Flood Control.** Benefits and costs for flood control protective works to be constructed prior to 1980 are shown in Table 4-14. The annual cost of adding an additional 84,000 acre-feet of flood control storage to the existing flood control storage in the Upper Baker River storage project was determined by computing the annual power losses that could be expected. Purchase of power in kind from the Bonneville system was the basis of the annual cost determination. Annual costs for a single-purpose flood control storage project on the Lower Sauk River, the Avon Bypass Project, and channel and levee construction include interest and amortization of the total investment (including interest during construction), average annual costs of operation and the equivalent average annual cost of major replacements. An interest rate of 4-5/8 percent was used to compute interest during construction and the annual cost of interest and amortization. An economic life of 100 years was used on storage projects and an economic life of 50 years, for levee construction.

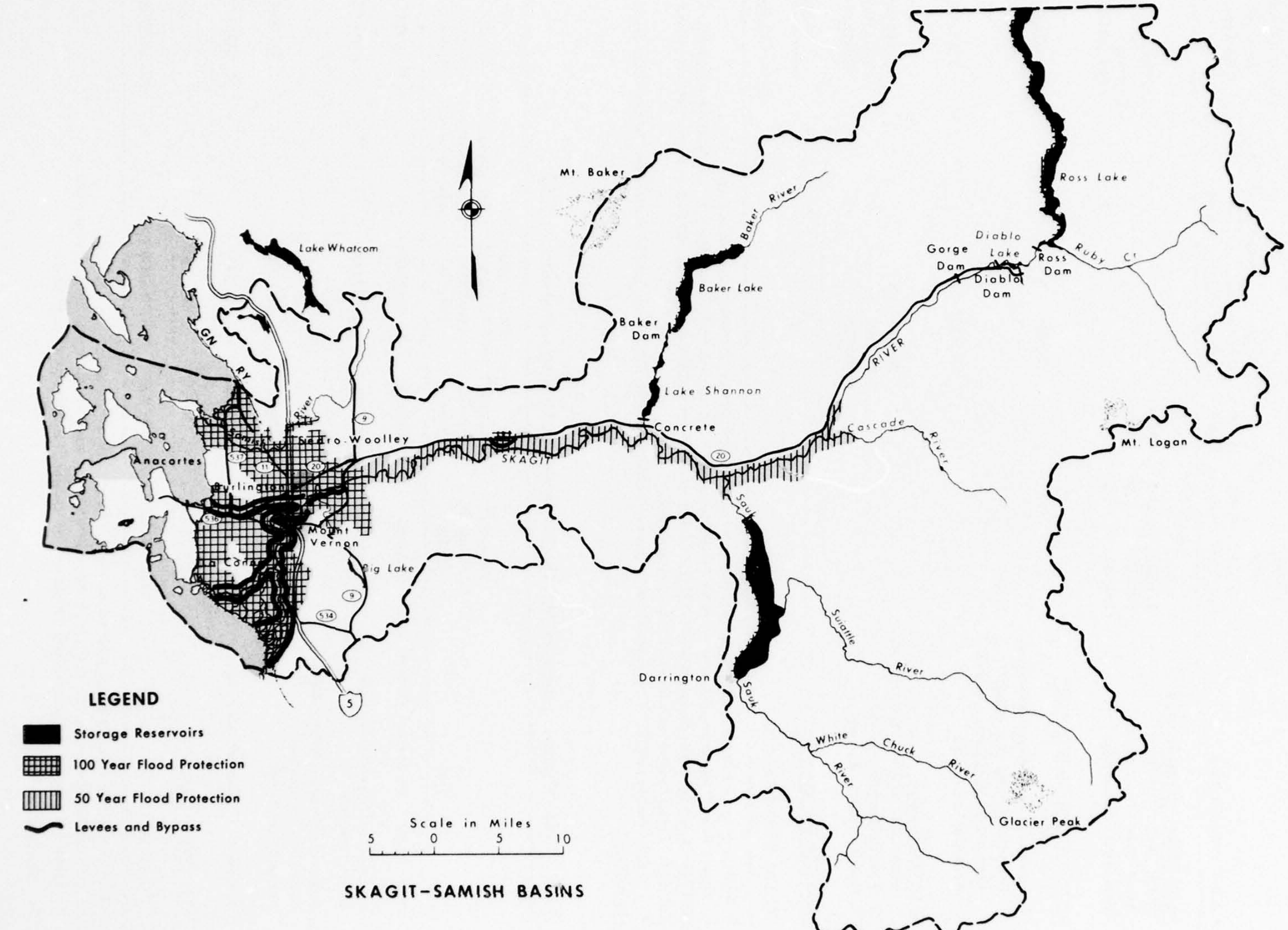



FIGURE 4-10. Proposed flood control plan and accomplishments

## TABLE 4-13. Flood control plan

| Flood Control Feature | Effective Flood Control Storage Acre-Feet | River Mile | Height of Dam Feet | Design Capacity cfs | Sequence of Dev. to 1980 | to 2000 | to 2020 | Estimated Dev. Costs for Proj. Based on 1968 Costs |
|---|---|---|---|---|---|---|---|---|
| Flood Control Storage Projects | | | | | | | | |
| Skagit River—Ross Dam | 120,000 | 102.7 | 540 | | | | | Existing[1] |
| Baker River—Upper Baker | 100,000 | 9 | 330 | | X | | | Existing[2] |
| Sauk River—Lower Sauk | 134,000 | 5 | 170 | | | X | | $61,200,000 |
| Channel and Levee Construction | | | | | | | | |
| 1. Avon Bypass | | | | 60,000 | X | | | $28,900,000 |
| 2. Levee and channel improvements from the Burlington—Mount Vernon area downstream to the mouth of both Forks | | | | 120,000 | X | | | 7,000,000 |
| Levee Construction | | | | | | | | |
| 1. Nookachamps Creek Area—5.5 mi. | | | | 135,000 | X | | | 2,500,000 |
| 2. Town of Hamilton—3 miles | | | | 180,000 | | X | | 2,800,000 |
| 3. Sedro Woolley—4 miles | | | | 180,000 | | X | | 3,000,000 |
| Flood Plain Management | | | | | X | X | X | 2,500[3] |
| TOTAL COST OF PLAN | | | | | | | | $105,402,500 |

1 Ross Dam and Reservoir on the Skagit are presently operated to provide this flood control storage.
2 Upper Baker Reservoir presently provides 16,000 acre-feet of storage to compensate for lost natural channal storage. The FPC license requires that an additional 84,000 acre-feet of flood control storage be provided in the existing project providing that power losses incurred are satisfactorily compensated.
3 Skagit County and State of Washington implementation costs only. Cost of completed Flood Plain Information Study is not included.

## TABLE 4-14. Estimated costs and benefits for projects to be constructed prior to 1980

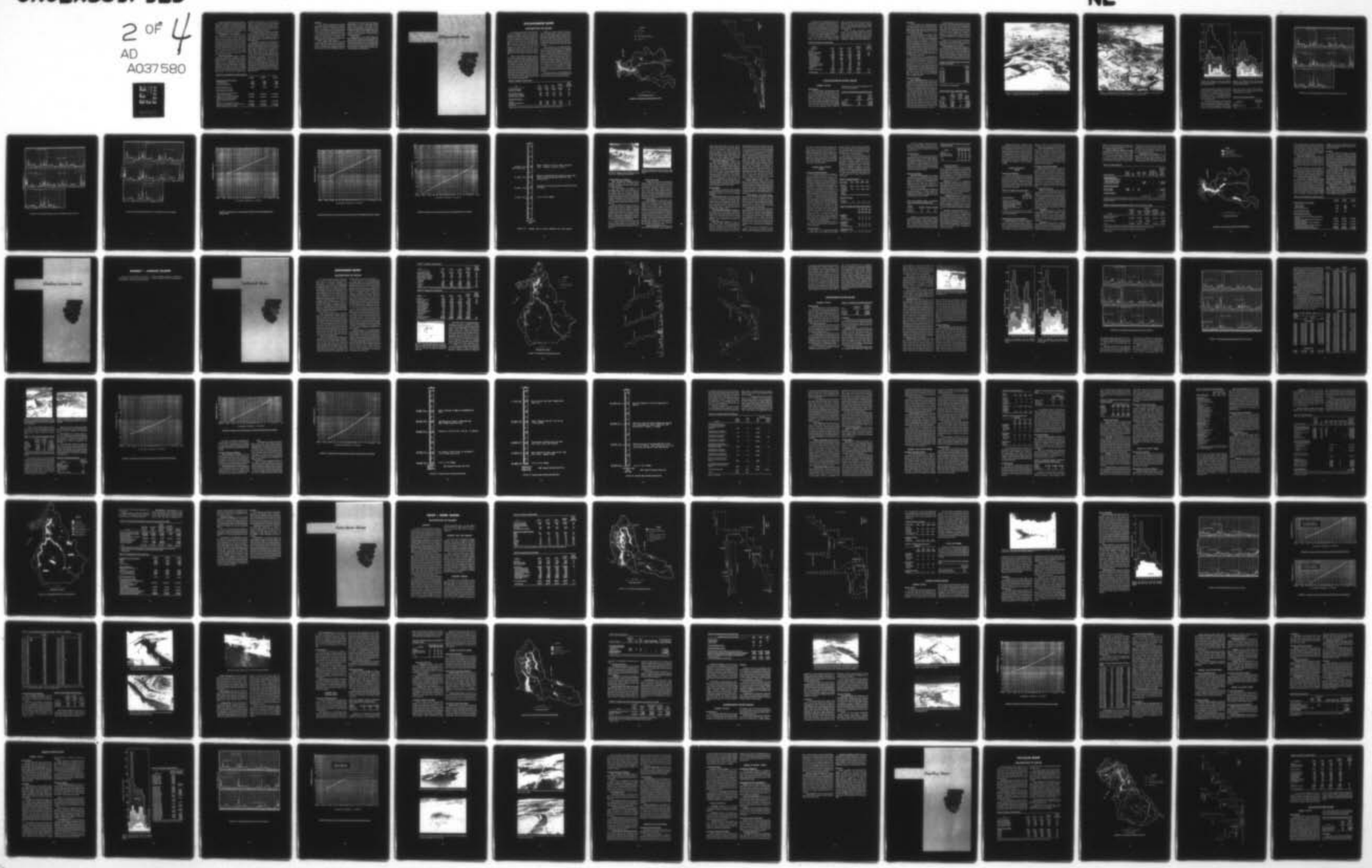
| Project | Estimated[4] Total Constr. Costs | Estimated[4] Annual Costs | Est. Annual Flood Damage Prevention Benefits | Est. Annual Land Enhance-ment Benefits | Total Annual Benefits |
|---|---|---|---|---|---|
| Upper Baker River Storage Project[1] | Existing | $ 133,000 | $ 300,000 | -- | $ 300,000 |
| Avon Bypass Including Upstream Levee extension | $28,900,000 | 1,500,000 | 2,147,000 | -- | 2,147,000 |
| Levee and Channel Improvements—Burlington downstream to mouth of both forks | 7,000,000 | 370,000 | 853,000 | -- | 853,000 |
| Levees at Nookachamps Creek Area | 2,500,000 | 135,000 | 150,000 | -- | 150,000 |
| Flood Plain Management | -- | 8,400[2] | 483,000[3] | -- | 483,000 |
| Total Cost | $38,400,000 | $2,146,400 | $3,933,000 | | $3,933,000 |

1 Project operation would be changed to provide for flood control storage.
2 Includes Federal, Skagit County, and State of Washington administration and enforcement costs.
3 Based on reduction of future flood damages in the buildings and equipment category.
4 1968 price level.

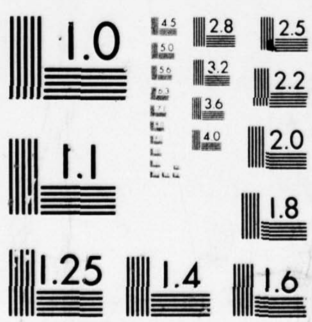
AD-A037 580 PACIFIC NORTHWEST RIVER BASINS COMMISSION VANCOUVER WASH F/G 8/6
COMPREHENSIVE STUDY OF WATER AND RELATED LAND RESOURCES. PUGET --ETC(U)
MAR 70 A T NEALE, S STEINBORN, L F KEHNE

UNCLASSIFIED NL

2 OF 4
AD
A037580



A03758




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Flood control benefits are based on the reduction of flood damages by combined operation of all elements of the flood control plan. Benefits include reduction of damage to the existing developments and to estimated future growth and are based on 1966 prices. The 1980 projects are considered to be constructed at or near the same time period.

**Accomplishments.** Accomplishments of the flood control plan are shown in Table 4-15. Protection in excess of 50 years would be provided to Mount Vernon, Burlington, LaConner, Edison, and Lyman by 1980 and would be provided to the towns of Hamilton and Sedro Woolley by the year 2000. Protection in excess of 50 years would be provided to the agricultural flood plain west of the town of Sedro Woolley. Agricultural lands located upstream of Sedro Woolley would be provided a 15 to 25-year level of protection. With the Lower Sauk River storage project the protection would exceed a 100-year level for the urban areas.

**Alternatives Considered.** Additional upstream storage was considered as a substitute for the proposed downstream control measures. Approximately 800,000 acre-feet of additional storage would be necessary to control a 100-year flood. This storage could be provided on the Skagit River. A preliminary investigation was made of the Faber and Copper Creek sites on the Skagit River, two sites on the Sauk River, two sites on the Suiattle River, one site on the Cascade River, and one site on Thunder Creek. Obtaining flood protection by storage alone was found to be much more expensive than combining upstream storage with levee and channel improvements and diversion. Storage at the Faber site was determined infeasible due to excessive costs and poor foundation and abutment conditions.

Flood plain evacuation to reduce flood damages is not economically feasible because of the prohibitively high cost of relocation of towns and numerous other improvements. This alternative would not permit optimum urban or agricultural development of flood plain lands.

Flood plain management and floodproofing of existing buildings was evaluated as an alternative to major flood protective works for reduction of present and future flood damages. Extensive existing urban and industrial developments in the communities of Mount Vernon, Sedro Woolley, Burlington, LaConner, Edison, Hamilton, and Lyman as well as numerous residences and associated buildings located in rural areas of the flood plain would require floodproofing. Approximately 30 percent of the estimated $3,020,000 average annual flood damages, or about $900,000, occurs to buildings. A high percentage of these buildings are wood frame construction and floodproofing would require structural treatment that is economically infeasible. This alternative would not meet the present or future needs for optimum development and utilization of the Skagit Basin flood plain.

**TABLE 4-15. Accomplishments of flood control plan**

| | to 1980 | to 2000 | to 2020 |
|---|---|---|---|
| Acreage Protected by Structural Measures | | | |
| 100 year protection | 4,000 | 70,000 | 70,000 |
| 25 to 50 year protection | 64,000 | 5,000 | 5,000 |
| Less than 25 year protection | 22,000 | 15,000 | 15,000 |
| Flood Plain Management (Acres) | 86,000 | 20,000 | 20,000 |
| Flood Damage Prevention (Dollars) | | | |
| Projected average annual flood damages without additional protection. | $4,340,000 | $7,060,000 | $12,030,000 |
| Reduction in future average annual flood damages due to flood plain management | $ 345,000 | $1,230,000 | $ 3,015,000 |
| Projected residual average annual flood damages with flood plain management. | $3,995,000 | $5,830,000 | $ 9,015,000 |
| Reduction in future average annual flood damages with implementation of structural measures. | $3,885,000 | $5,683,000 | $ 8,778,000 |
| Residual average annual flood damages. | $ 110,000 | $ 147,000 | $ 237,000 |

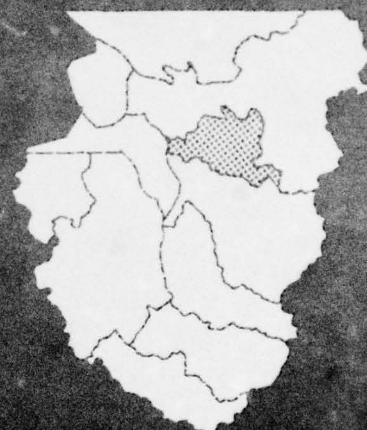
## Summary

In the 90,000 acre flood plain of the Skagit-Samish Basins, extensive agricultural and urban developments are exposed to excessive flood hazards. Levees, in combination with the existing upstream flood storage, are capable of providing only three to 15 year protection to the 68,000 acre flood plain west of Sedro Woolley. No levee protection exists upstream of Sedro Woolley and flooding occurs annually. Annual flood damages are estimated to be $3,020,000 at 1966 prices and conditions.

Flood damage studies indicate that future average annual flood damages may be expected to increase in proportion to the increase in economic activity in the flood plain if additional protection is not provided. The trend of development within the basin could result in future growths of flood damages approximating 2½ percent compounded annually without flood control and could result in future growth of annual damages to $4,340,000 in 1980, $7,060,000 in 2000, and $12,030,000 in 2020. These existing and projected flood damages should be reduced to allow development of the full economic potential of the basin.

Implementation of the flood control plan would significantly reduce flood plain damages and permit increased utilization of the flood plain. One hundred year protection would be provided to urban areas within the flood plain. Prime agricultural lands would be provided with protection in excess of 50 years. Overflow of the Skagit River floodwaters into the Samish Basin would be prevented.

# Stillaguamish Basin



# STILLAGUAMISH BASIN

## DESCRIPTION OF BASIN

The Stillaguamish River Basin is about 40 miles long, has a maximum width of 30 miles, and comprises approximately 690 square miles. Seventy-five percent of the basin is in Snohomish County and 25 percent in Skagit County. The basin, Figure 5-1, is bounded on the north and east by the Skagit River Basin and on the south by the Snohomish River Basin. The North and South Forks join near Arlington to form the main stream. From the city of Arlington, the broad, fertile flood plain of the Stillaguamish River extends westward 23 miles to Skagit Bay and Port Susan, arms of Puget Sound. Profiles of the stream system are shown on Figure 5-2.

Soils of the mountainous areas in the eastern part of the watershed consist of shallow mantles of loams, stony and rocky loams overlying bedrock of limestone, basalt, slate, shale, schist, gneiss, granite and quartzite. Soils of the western part of the basin were formed in cemented sandy glacial till, glacial clay till and outwash glacial sands and gravels. Their textures are loams, clay loams, sandy loams, gravelly sandy loams, sands and gravelly sands. The flood plains consist of sands and gravelly sands in the upper reaches and become progressively finer textured to fine sandy loams, silt loams, loams, clay loams and silty clay loams in the lower reaches. Peats and mucks occur in many small drainage basins.

Maritime air masses influence both precipitation and temperatures in the basin, producing a mild, wet climate. Approximately 75 percent of the precipitation falls during the period October through March. The average annual precipitation varies from 35 inches near the mouth to more than 100 inches at the headwaters. The mean annual temperature ranges from 50°F. at Stanwood to 47°F. in the eastern part of the basin.

Urban development in the Stillaguamish Basin has not been greatly influenced by the expanding Seattle, Tacoma, Everett metropolitan area. Built-up areas are confined almost exclusively to the western part of the basin which contained 95 percent of the population in 1960. Principal towns in the basin are Arlington, Stanwood, and Granite Falls. Table 5-1 gives historic population figures for these towns and the basin. The increase in population for the basin from 15,900 in 1960 to 18,300 in 1967 represents an annual growth rate of about 2.6 percent as compared to 3.2 percent for the preceding two decades (1940-1960). This lower growth rate is partially attributable to reduced activities in the forest product industry.

The natural resources of the Stillaguamish Basin are limited primarily to forests, agricultural lands, and outdoor recreation, primarily hunting and fishing.

**TABLE 5-1. Population—past and present**

| Area | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| United States (thousands) | 132,164 | 151,326 | 179,323 | 200,100 | 52 |
| Puget Sound (thousands) | 1,007 | 1,418 | 1,768 | 2,100 | 105 |
| Central Division (thousands) | 820 | 1,196 | 1,513 | 1,751 | 114 |
| Snohomish County (thousands) | 88.8 | 111.6 | 172.2 | 224.4 | 150 |
| Stillaguamish Basin (thousands) | 8.2 | 10.3 | 15.9 | 18.3 | 112 |
| Cities and Towns in Basin | | | | | |
| Arlington | 1,460 | 1,635 | 2,025 | 2,195 | 50 |
| Stanwood and East Stanwood | 960 | 1,090 | 1,120 | 1,240 | 29 |
| Granite Falls | 680 | 635 | 600 | 650 | -5 |

Figures are from U.S. Census Report; Seattle Area Industrial Council, 1967, and Appendix IV, Economics.

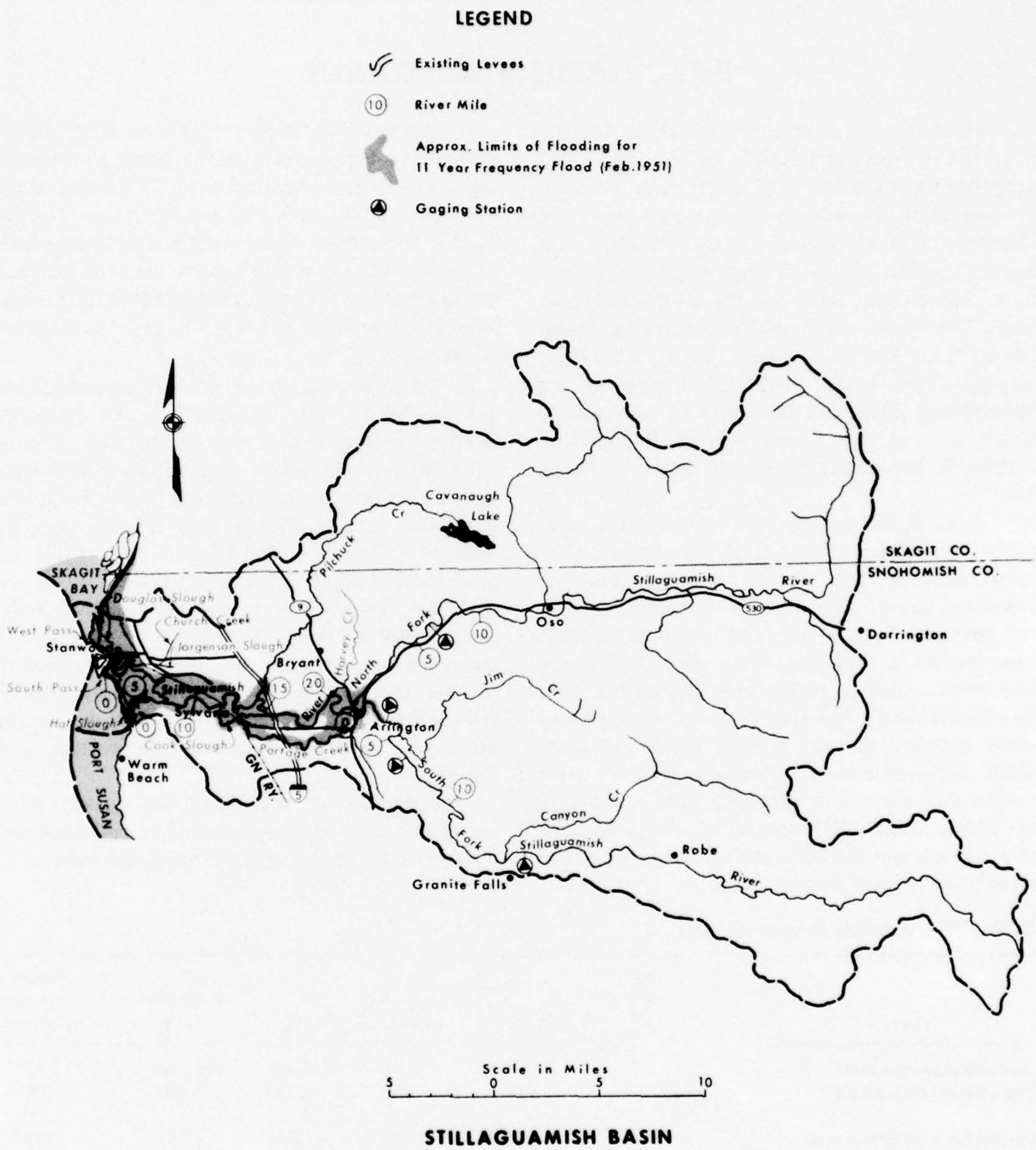
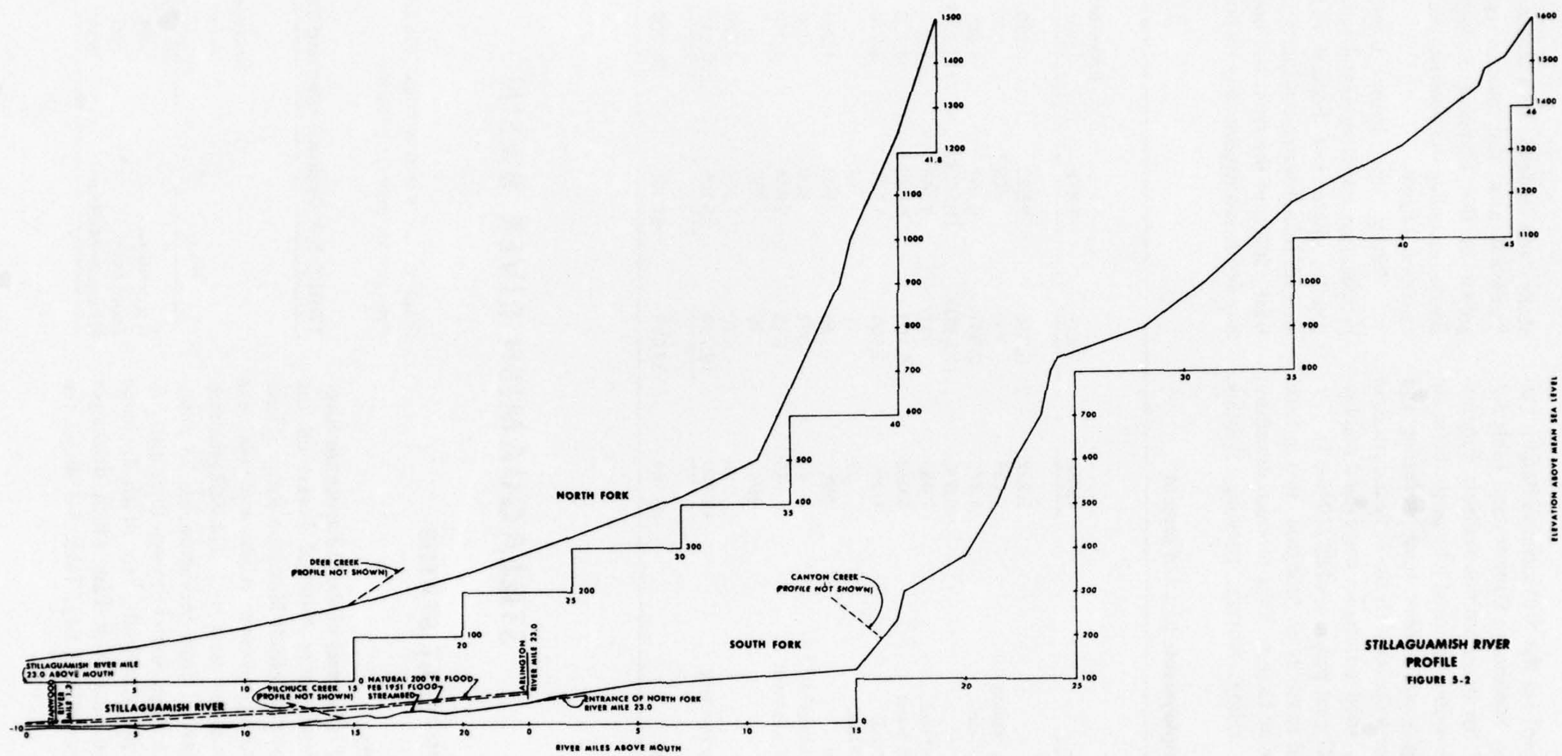



**FIGURE 5-1. Flood plain and existing protective works**




STILLAGUAMISH RIVER
PROFILE
FIGURE 5-2

Employment for the Stillaguamish Basin is best demonstrated by Snohomish County data, Table 5-2, as statistics for the basin are not available. Employment sectors providing principal jobs in the basin are agriculture, logging and lumber, food processing, and trade and service industries. Of the basic industries in this group only food processing has gained employment over the 27-year period studied (1940-67).

Five small sawmills at Arlington, two in Stanwood, and one at Granite Falls produce dimension lumber, cedar siding, fencing, paneling, flooring, shakes and shingles. Two frozen food plants in the Stanwood area also process agricultural products grown in the adjoining Stillaguamish and Skagit Basins, including strawberries, peas, cauliflower, corn, carrots and beans.

Within the basin, transportation facilities include two transcontinental railroads, a network of county, State and Federal roads, and a private airfield. Inland water transportation is limited to the tidal portion of the river, and under present controlling depth, is navigable only by boats of light draft.

**TABLE 5-2. Employment—past and present**

| Industry Description | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| Agriculture | 3,737 | 3,636 | 2,523 | 3,980 | 7 |
| Forestry, Fishing, Mining | 188 | 400 | 403 | 576 | 206 |
| Contract Construction | 1,375 | 2,947 | 4,741 | 5,405 | 293 |
| Manufacturing | (8,836) | (10,301) | (16,427) | (19,828) | (124) |
| Food & Kindred Prod. | 480 | 771 | 1,341 | 1,800 | |
| Lumber, Wood & Furn. | 6,083 | 5,703 | 5,499 | 4,200 | |
| Paper & Allied Prod. | 1,343 | 2,500 | 3,125 | 3,200 | |
| Chem. & Allied Prod. | 37 | 71 | 98 | -- | |
| Fabricated Metal | NA | 195 | 562 | 1,200 | |
| Mach. (Elect. & Non-Elect.) | 40 | 302 | 892 | 800 | |
| Transportation Equipment | 145 | 613 | 2,834 | 4,000 | |
| Primary Metals | NA | 76 | 151 | -- | |
| All Other | 708 | 70 | 1,924 | 4,628 | |
| Non-Commodity Industry | 12,622 | 19,797 | 33,105 | 36,911 | 192 |
| Total Employment | 26,854 | 37,081 | 57,199 | 66,700 | 315 |

# STILLAGUAMISH RIVER BASIN

## PRESENT STATUS

### Stream System

The major tributaries of the Stillaguamish River rise in the Mount Baker National Forest on the western slopes of the Cascade Mountain Range. These streams flow through narrow valleys and join near Arlington to form the main river. The Stillaguamish River flows westward from Arlington for 23 miles and empties into Puget Sound through three distributaries: Hat Slough and South Pass which discharge into Port Susan, and West Pass which discharges farther north into Skagit Bay. Table 5-3 shows the drainage areas and average annual discharges of the river and its main tributaries.

**TABLE 5-3. Drainage areas and average annual runoff**

| River | Drainage Area (Sq. Mi.) | Average Annual Runoff (Acre-Feet) |
|---|---|---|
| North Fork | 284 | 1,358,000 |
| South Fork | 255 | 1,323,000 |
| Stillaguamish River | 684 | 2,940,000 |

## Flood Plain

The flood plain of the Stillaguamish River contains about 12,600 acres of fertile land (see Figure 5-1). Below Silvana, tides raise river stages and hamper drainage. The fertile, fine grained soils in the flood plain are highly subject to erosion from flows of even moderate velocities.

The narrow flood plains of the South and North Forks range from one-fourth to one mile in width. Between Arlington and Silvana, the Stillaguamish flood plain is one to two miles wide. The flood plain broadens downstream from Silvana to a wide delta containing approximately 7,000 acres of farm land and the communities of Stanwood, Florence, and Norman. Major industries in these towns are related to agriculture and include the processing and freezing of fresh foods and dairy products. Some of the sawmills in Stanwood and Arlington are subject to flooding. Photos 5-1 and 5-2 show urban and rural development in the flood plain.

The coastal routes of two mainline railroads, the Great Northern and the Northern Pacific, cross the flood plain. Interstate Highway 5, also crosses the flood plain between Silvana and Arlington and is connected by a network of county roads to all population centers in the basin. Twenty roadway and six railroad bridges cross the Stillaguamish River and its tributaries. Several important high voltage power transmission lines, telephone trunk lines, natural gas lines and water lines also cross the Stillaguamish Basin. No significant amount of water is diverted from the Stillaguamish River.

## History of Flooding

**Flood Characteristics**—High flows on the Stillaguamish River follow the general runoff pattern of other rivers in the Puget Sound Area. The rain shadow of the Olympic Mountains extends to the lower part of the basin but has very little or no influence in the higher elevations. The combination of rising temperatues, heavy rainfall and rapid snowmelt following successive storms cause high discharges, usually in the fall or winter. Floodflows are characterized by a sharp rise, followed by a recession almost as rapid with two or more peaks often occurring within a period of two weeks. Peak flows during the winter months may be more than 300 times greater than minimum summer flows. These characteristics are shown for the North and South Forks in monthly discharges, Figures 5-3 and 5-4, and daily discharge hydrographs, Figures 5-5 and 5-6.

**Floods**—Streamflow records have been maintained for the North and South Forks near Arlington since 1928, and for the main stem at Arlington since 1947. Major flood damages result from flows of 53,000 cfs or more. This discharge has been equaled or exceeded at least 9 times since 1932, as shown in Table 5-4. The zero damage flow, measured at Arlington, is considered to be 37,000 cfs. Between 1932 and 1965, this flow was exceeded at least 43 times.

Figures 5-7, 5-8 and 5-9 show the estimated probability of annual maximum peak flows for the South Fork above Jim Creek, the North Fork near Arlington, and the main stem at Arlington.

**Flood Damages**—The most recent appraisal of flood damages in the flood plain below Arlington was made in January 1961. A field reconnaissance updated the 1961 appraisal to 1966 prices and conditions, noted growth in the flood plain since 1961, and adjusted previous appraisals to current land values. The estimated damages from selected flows are shown in Table 5-5. The average annual flood damage, based

**TABLE 5-4. Peak discharges greater than zero damage (37,000 cfs at Arlington)**

| Date | Discharge (cfs)[1] |
|---|---|
| Feb. 1932 | 65,000 |
| Nov. 1932 | 56,000 |
| Jan. 1935 | 55,000 |
| Feb. 1951 | 61,000 |
| Dec. 1956 | 55,000 |
| Nov. 1958 | 58,500 |
| Nov. 1959 | 59,600 |
| Dec. 1959 | 54,800 |
| Feb. 1960 | 53,000 |

[1] Estimated flow from upstream gages.

**TABLE 5-5. Major floods and estimated damages**

| Date or Frequency | Peak Discharge at Arlington (cfs) | Average Recurrence Interval (Years) | Current Estimated Damages |
|---|---|---|---|
| Feb. 1932 | 65,000 | 14 | $ 890,000 |
| Feb. 1951 | 61,000 | 11 | 705,000 |
| Nov. 1959 | 59,600 | 9 | 655,000 |
| 50-year flood | 82,000 | 50 | 2,180,000 |
| 100-year flood | 93,000 | 100 | 3,355,000 |

PHOTO 5-1. Stillaguamish River delta area. Whidbey and Camano Islands are shown in the upper portion of the photo (Courtesy of Northwest Air Photos—July 1964).

PHOTO 5-2. Stillaguamish River delta area looking upstream. The town of Stanwood and the Stillaguamish River are shown in the foreground (Courtesy of Northwest Air Photos—July 1964).

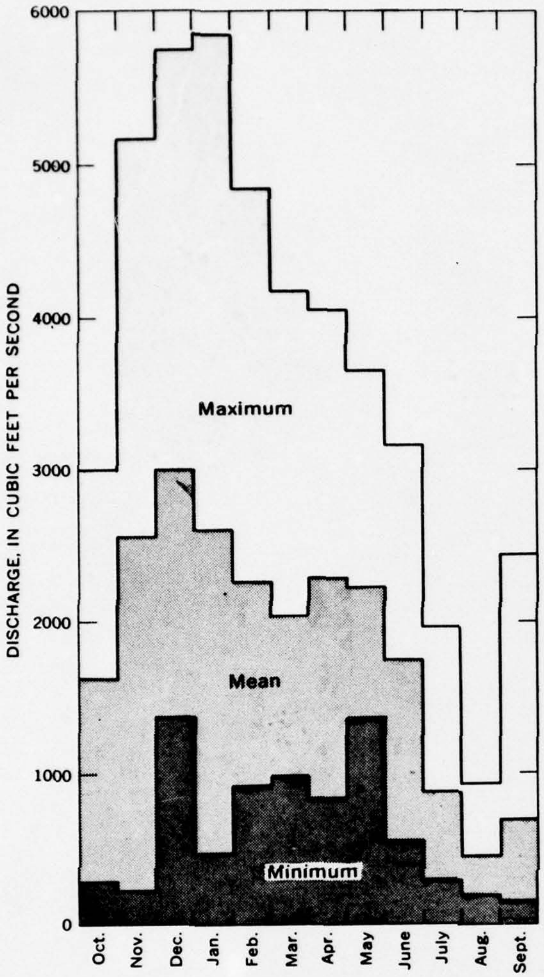



FIGURE 5-3. Maximum, mean and minimum monthly discharges, North Fork Stillaguamish River near Arlington, 1931-60.

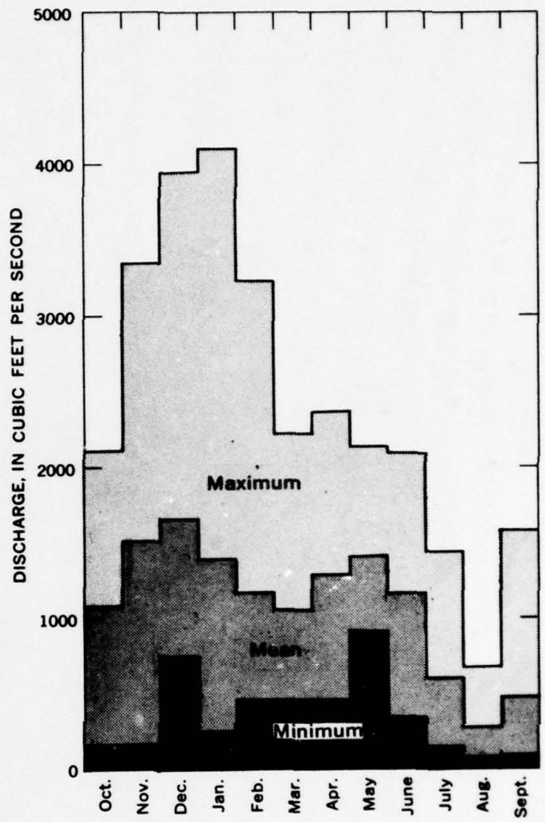



FIGURE 5-4. Maximum, mean and minimum monthly discharges, South Fork Stillaguamish River near Granite Falls, 1931-60.

on these same appraisals, is estimated to be $256,000 at 1966 prices and conditions. Photos 5-3 and 5-4 show the town of Stanwood during the flood of November 1959. Figure 5-10 shows progressive stages of flooding measured at the Arlington gage. This figure illustrates the impact of flooding on transportation and community life.

In the agricultural setting of the Stillaguamish Basin, the greater part of flood damage is to land and crops, related buildings and equipment and highways. Table 5-6 tabulates flood damages by major damage categories and shows the percentage of total damage that would result from major flood discharges. Further details on flood damage appraisals are given in the Puget Sound Area section.

**TABLE 5-6. Flood damage distribution**

| Category | Percent of Total Damages |
|---|---|
| Agriculture | 39 |
| Buildings and Equipment | 50 |
| Other | 11 |

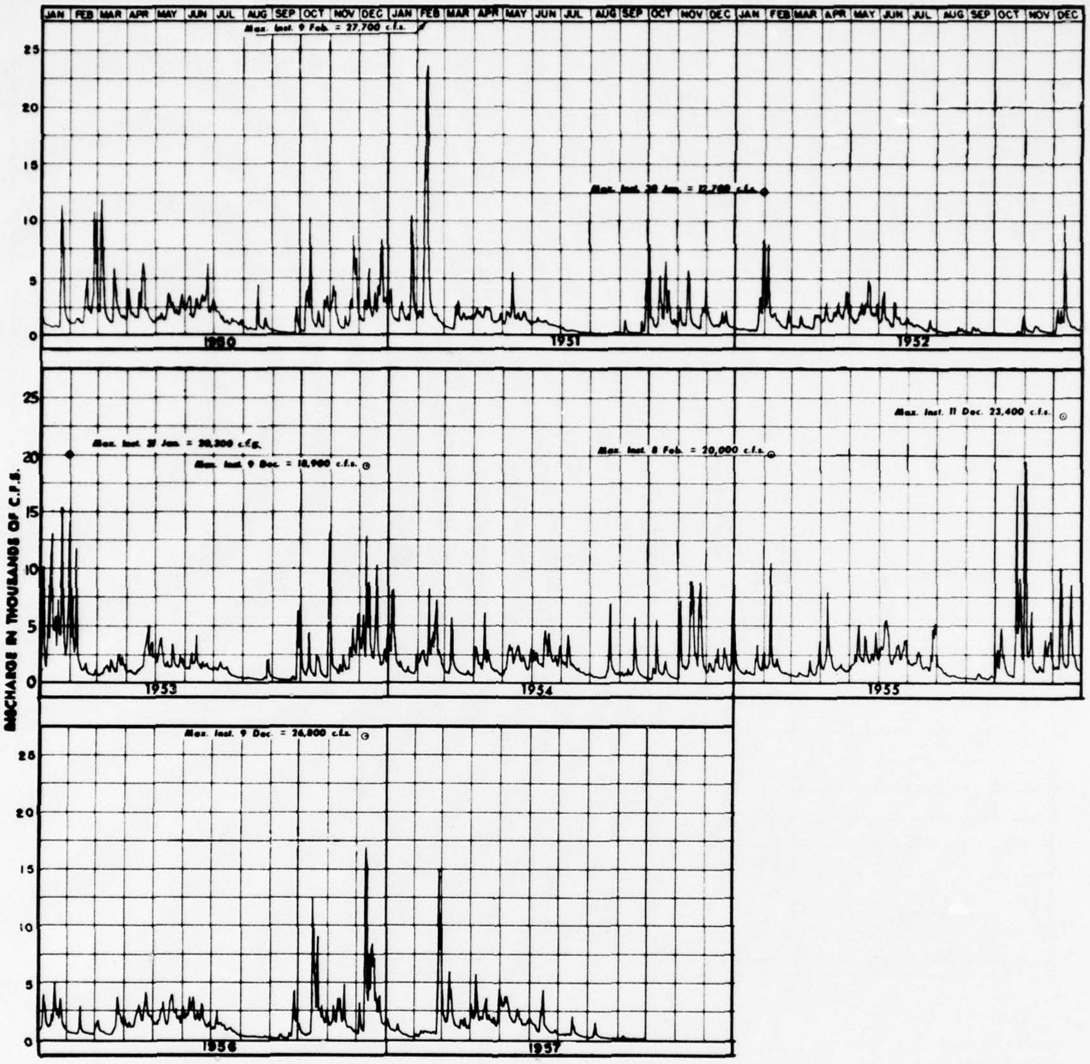



FIGURE 5-5. Daily discharge hydrograph, South Fork Stillaguamish above Jim Creek.

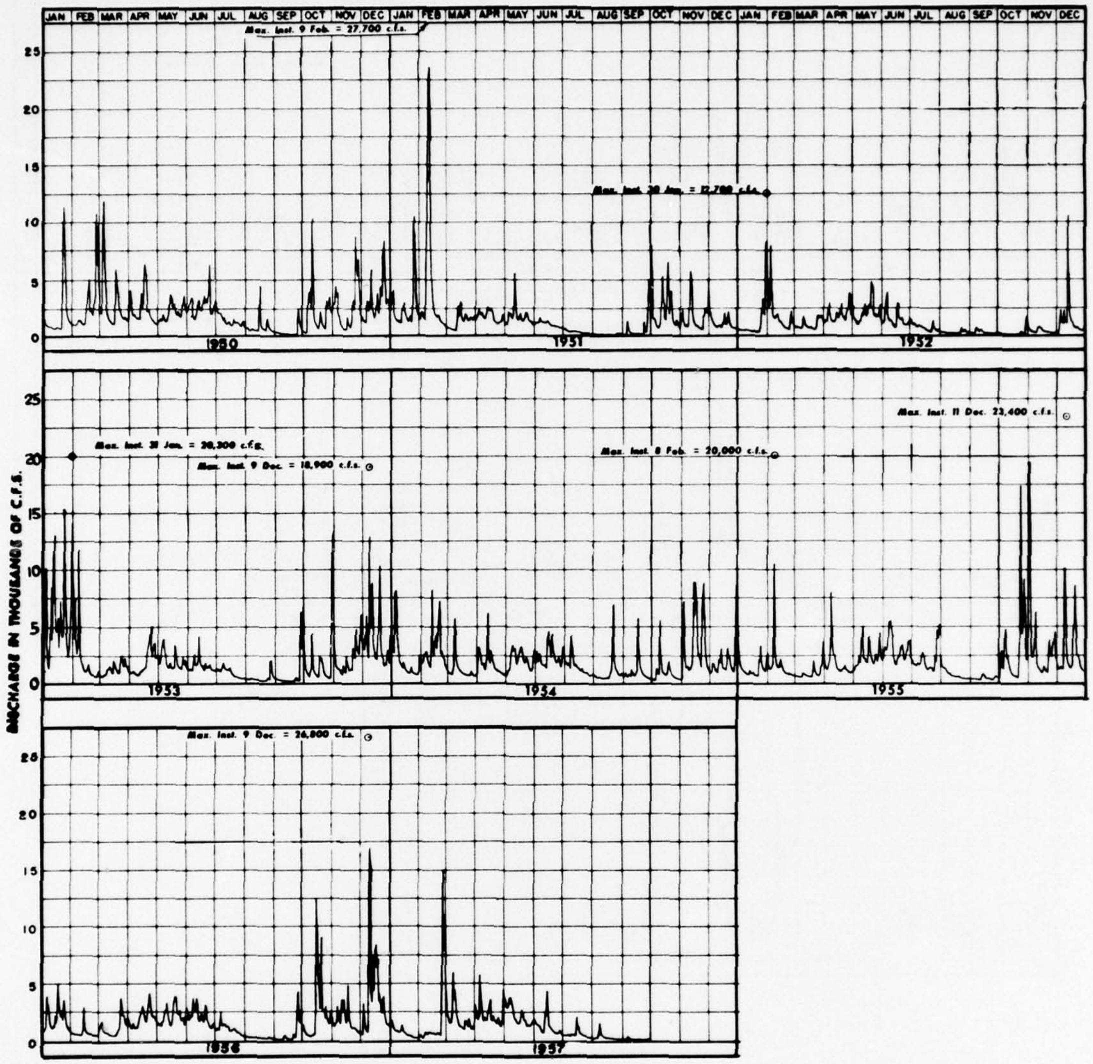



FIGURE 5-5. Daily discharge hydrograph, South Fork Stillaguamish above Jim Creek.

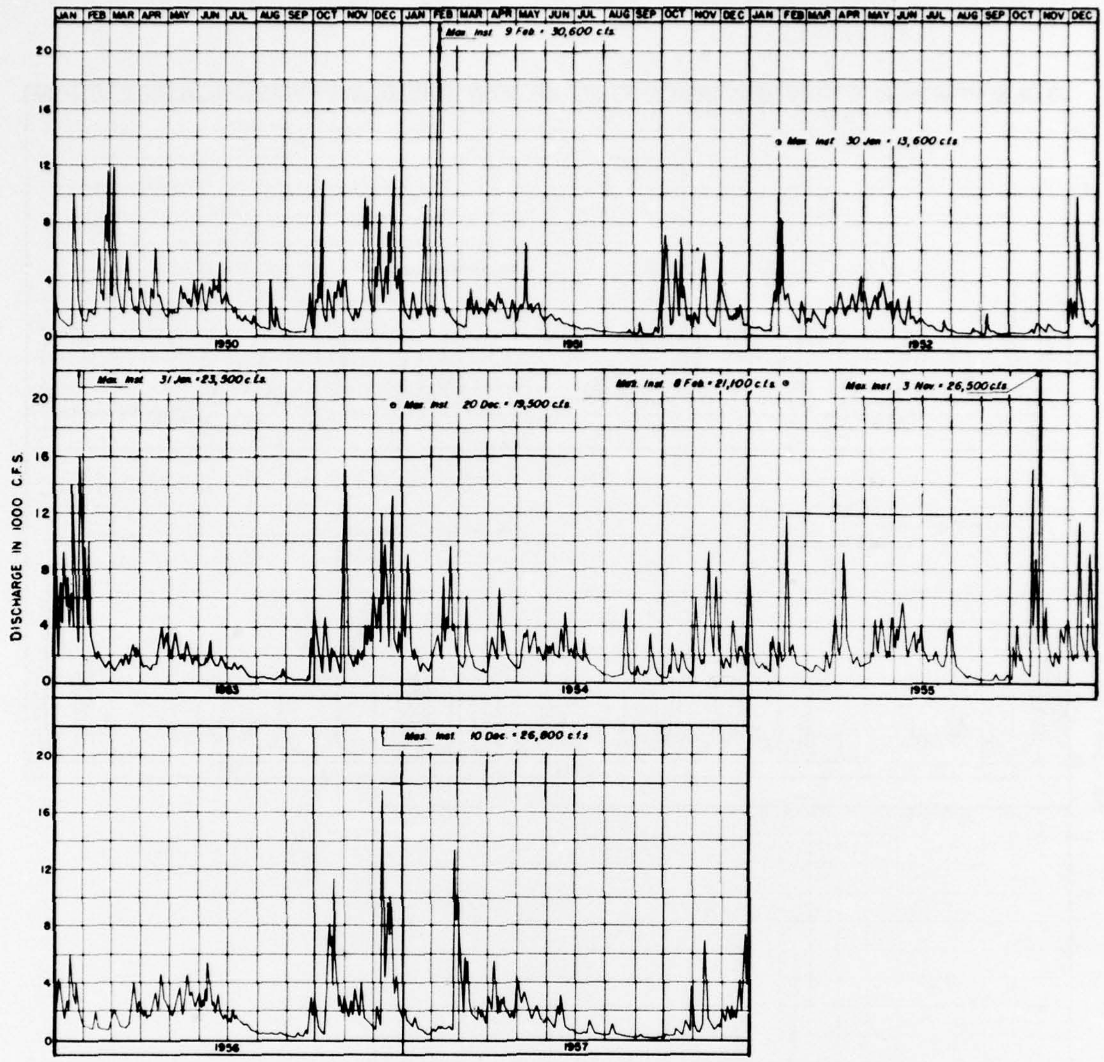



FIGURE 5-6. Daily discharge hydrograph, North Fork Stillaguamish River near Arlington.

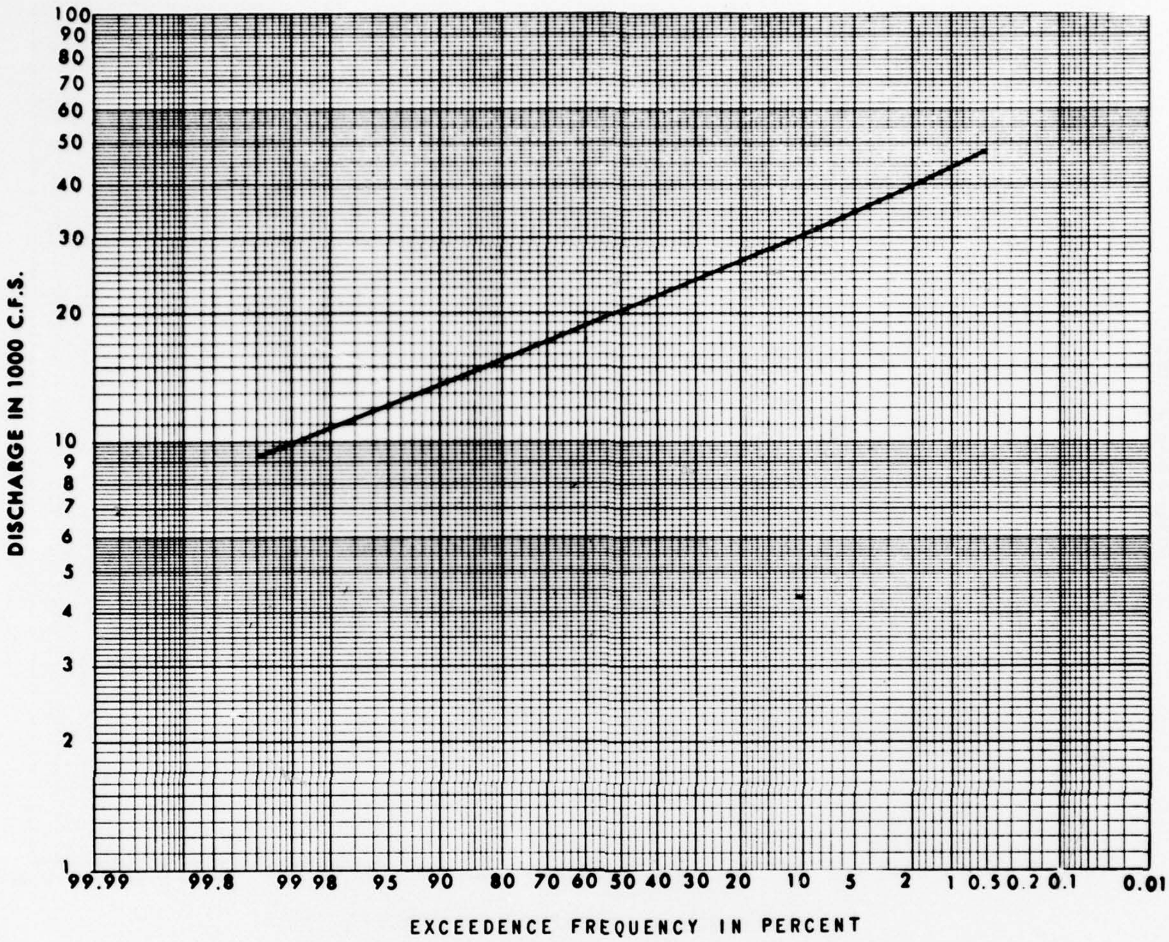



**FIGURE 5-7. Frequency curve of annual maximum peak flows, South Fork Stillaguamish River above Jim Creek**

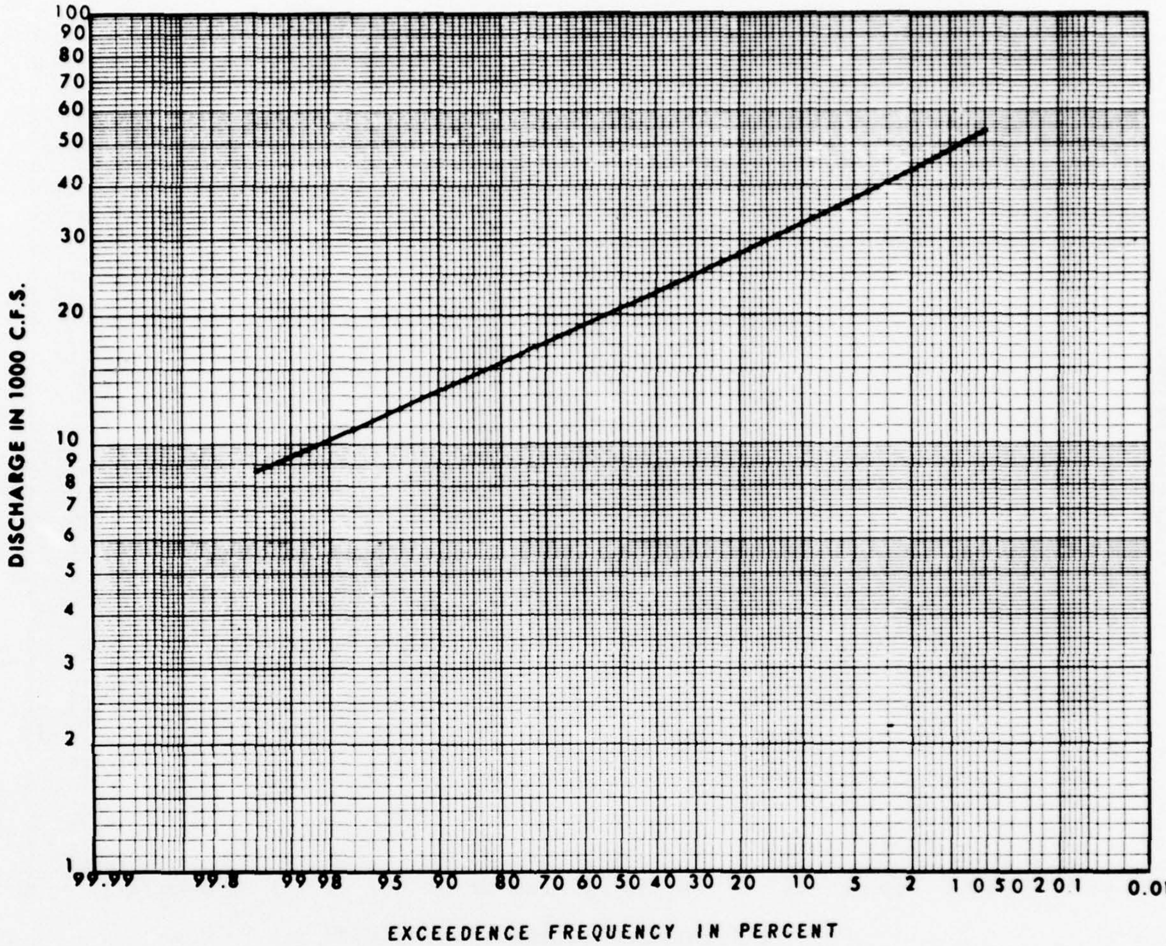



**FIGURE 5-8. Frequency curve of annual maximum peak flows, North Fork Stillaguamish River near Arlington**

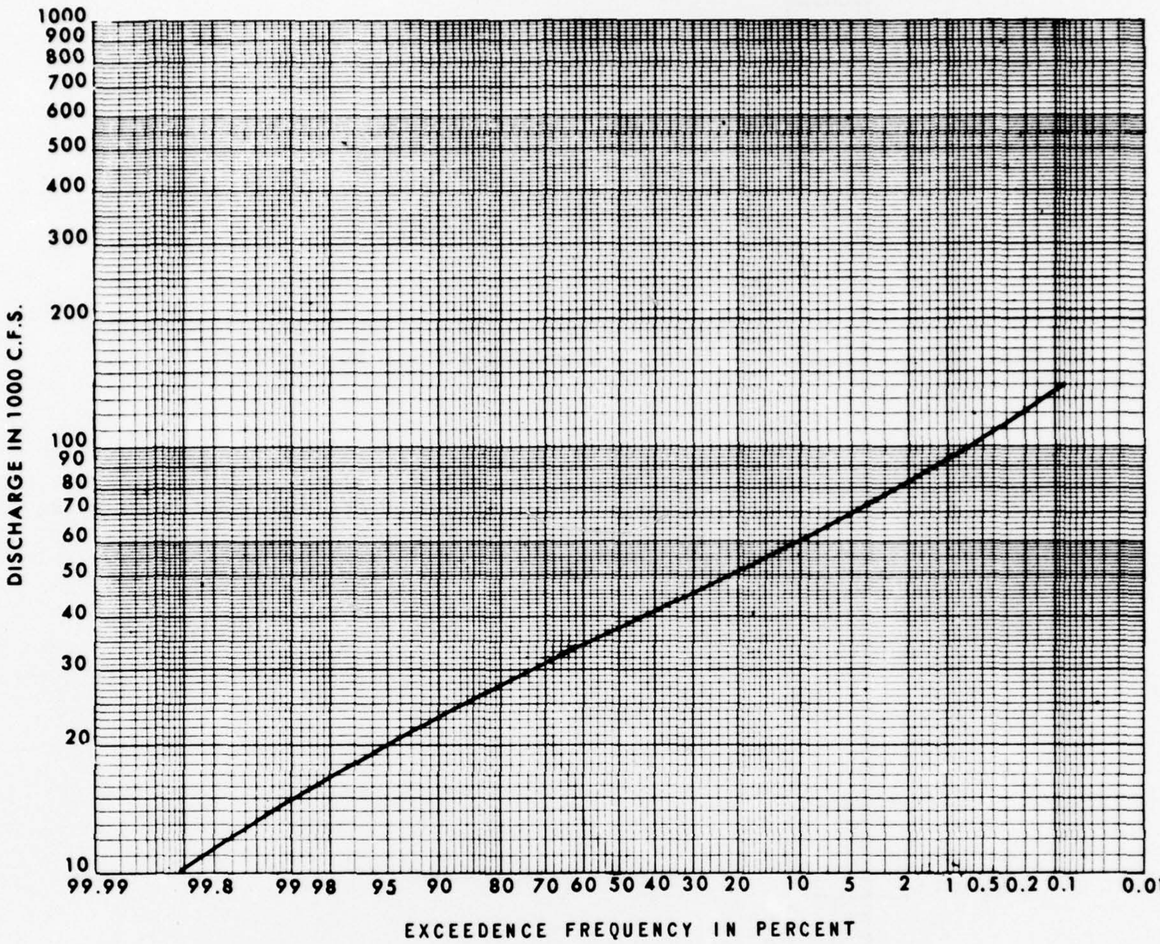



**FIGURE 5-9. Frequency curve of annual maximum peak flows, Stillaguamish River at Arlington**

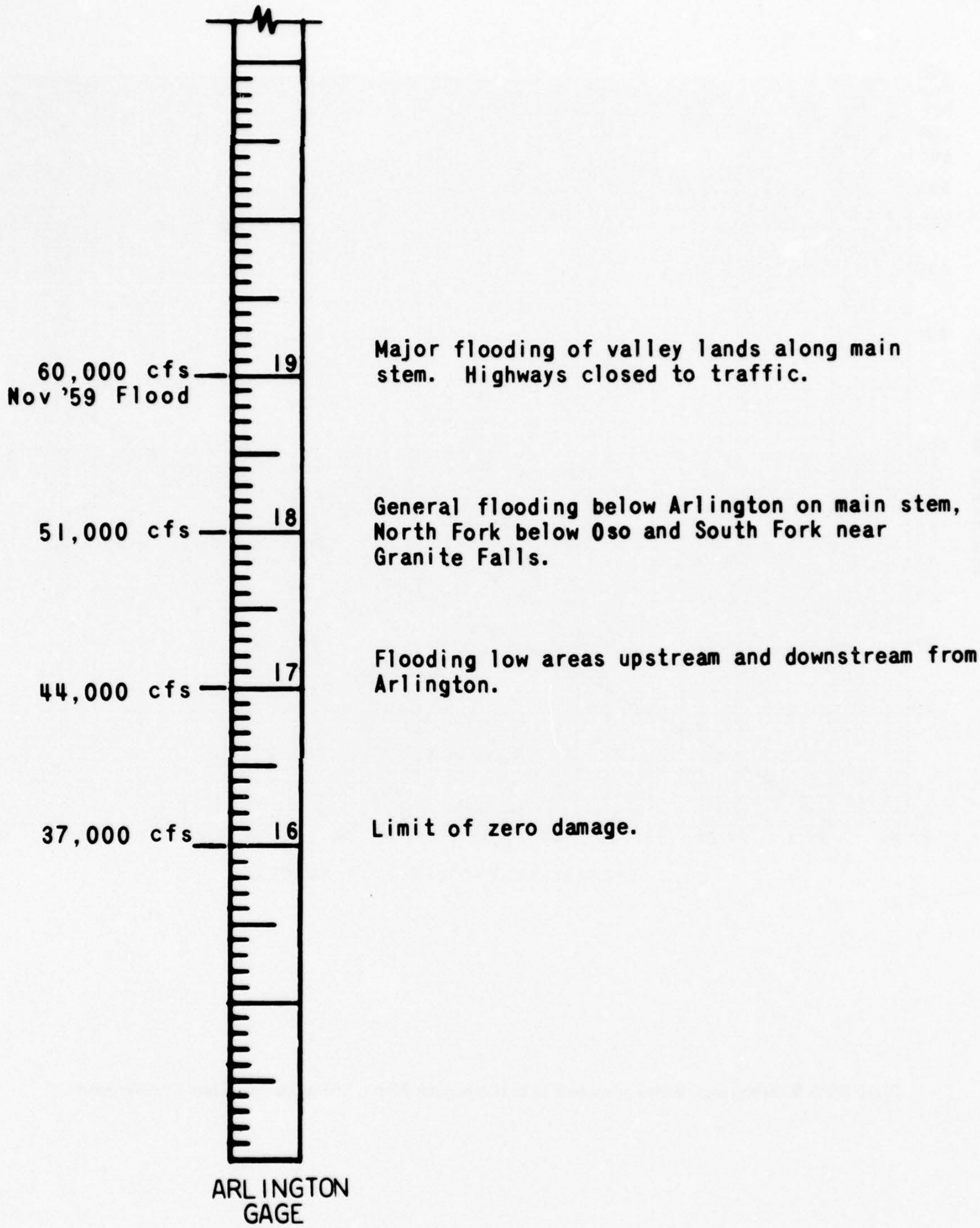



**FIGURE 5-10. Progressive stages of flooding, Stillaguamish River, 1960 conditions**

PHOTO 5-3. Stanwood and East Stanwood during flood of Nov. 1959 (Stanwood News Photo).

PHOTO 5-4. Stanwood, during flood of Nov. 1959, Stanwood High School in center (Stanwood News Photo).

## Existing Flood Control Measures

**Flood Forecasting and Warning**—The flood forecasting procedure of the U.S. Weather Bureau described in the Puget Sound Area section applies to the Stillaguamish Basin.

When flood forecasts are furnished to the Snohomish County Office of Civil Defense by the U.S. Weather Bureau and the Corps of Engineers, Civil Defense activates the Emergency Operation Control Center (EOC). Key personnel alerted through the call lists maintained by the office of Civil Defense establish communications with the EOC. The EOC operates on a 24-hour basis and maintains coordination with affected county agencies and the Corps of Engineers.

After the initial flood warning is issued, the Arlington Chief of Police is responsible for making periodic checks of the water elevation at the Arlington gage. These checks are made at 30-minute intervals and the information is reported to the Civil Defense Control Center. The Snohomish County sheriff cooperates with municipal police to assist the Director of Civil Defense in establishing and maintaining radio communications in the flood area.

If a flood is observed locally, such as a flash flood or flooding caused by a dike failure, the Snohomish County Engineer activates the EOC, alerts the county agencies affected, and advises the Corps of Engineers.

### Flood Protective Works

**Levees**—Levees have been constructed below Silvana by landowners, primarily to prevent flooding by high tides; however, levees along the main river and Hat Slough also prevent inundation from riverflows with an approximate recurrence interval of once in three years. During extremely high tides, some of these levees are overtopped. Levees near Stanwood on both the Stillaguamish River and South Pass, were overtopped by an extremely high tide in December 1967 and approximately 620 acres were flooded with salt water.

**Bank Protection**—To reduce bank erosion, the Federal Government constructed approximately 36,000 feet of revetments at 26 places between Arlington and Hat Slough, and on Cook Slough, between 1936 and 1939. In addition, the Corps of Engineers has constructed numerous emergency bank protective works. The latest project constructed was to protect the Mountain Fork Highway on the South Fork, completed on 1 May 1964 at a cost of $46,000. Including this project, the Corps of Engineers has expended a total of $163,000 during the period 1946 to 1964. Local landowners also have constructed significant bank protective works with assistance by the Agricultural Stabilization and Conservation Service, the State and Snohomish County.

**Channel Improvements**—In conjunction with the Federal bank stabilization project completed in

1939, channel improvements were made on Cook Slough. Local interests provided necessary rights-of-way. This work included a concrete weir 275 feet long at the head of Cook Slough to limit flow through the Slough and two cutoff channels, each about 900 feet long, to eliminate sharp bends in the slough. The $18,000 average annual maintenance given for the bank stabilization project includes maintenance of these channel improvements.

**Flood Plain Management**—In February 1963, the Corps of Engineers published a report on a flood plain study of the Stillaguamish River Basin. The report contains a description of the flood plain and a brief discussion of its geological origin; information on flow characteristics of the river and the magnitude and frequency of future floods; and suggests possible ways of minimizing potential flood damages, including preserving a minimum river channel, observing floodproofing practices, and restricting the density of developments in floodprone areas. The report was prepared to aid the county government in developing regulations for future occupancy and use of the flood plain. Snohomish County adopted flood plain zoning regulations on April 15, 1968.

## Flood Problems

The Stillaguamish River Basin suffers damaging floods approximately every three to five years. Flood problems are discussed by area in the following paragraphs:

**North and South Forks**—The stream gradients of the North and South Forks are relatively steep and the channels are well-defined. The primary flood problem is bank erosion during high river stages. Also, a few low sections of highways are closed to traffic. Some agricultural lands are inundated; however, because these valleys are sparsely populated and developed, flood damage is minor.

**Main River Between Arlington and Silvana**—In this 11-mile reach, the stream falls at an average rate of about four feet per mile. The flood plain of about 5,000 acres is a productive agricultural area in which dairying and row crop farming are the principal endeavors. Low, intermittent levees provide some flood protection.

**Main River Below Silvana**—The flood plain below Silvana sustains major flood damages. In addition to high flows on the Stillaguamish River, high tides on Puget Sound affect river stages. The 7,300-acre flood plain in this sector is occupied by a fully-developed farming community and the towns of Silvana and Stanwood. A levee system protects most of this area from spring floods; however, the levees are low, have narrow cross sections, and are incapable of withstanding floodflows in excess of about 45,000 cfs. Floods of this magnitude have a recurrence interval of approximately every three years. The low degree of protection has precluded full development of the agricultural and urban potential of the sector. Floods cause frequent and extensive damage to pasture and croplands, bridges, highways, and utilities, and interrupt the transport of produce to Everett and Seattle markets. Silvana and Stanwood frequently suffer considerable flood damage. In addition, Stanwood is sometimes flooded by overbank flows from the Skagit River to the north. Agricultural lands below Florence also suffer salt water intrusion, which could reduce their productivity for several years. During high tides on Port Susan and Skagit Bay, salt water enters through breaks in the levees caused by high river stages.

**Tributary Streams**—Tributary streams which drain into the North Fork, South Fork, and main river also experience flooding. The major cause of this flooding is inadequate drainage channels and outlets to permit these streams to discharge during periods when the main streams are flowing high. These small streams also experience drainage problems which are covered in Appendix XIV, Watershed Management, of this report.

**Church-Jorgenson and Douglas Sloughs**—Two branches of Church Creek originate in the rolling uplands north and east of Stanwood. From the junction of these branches, the Creek flows through a steep, narrow canyon to the Stillaguamish flood plain and terminates in Jorgenson Slough. The Slough discharges into the old main channel of the river about one mile southeast of Stanwood.

Douglas Slough flows into Skagit Bay north of Stanwood. Much of the flood plain is drained by surface ditches that discharge into the Stillaguamish River or Skagit Bay. The level, cultivated flood plain can be flooded by overbank flows of the Skagit River, the Stillaguamish River, or Church and Douglas Sloughs. Floodwater from the South Fork of the Skagit River enters this area by overtopping the dike on the east side of the South Fork. Floodwaters flow southward as far as Stanwood and the Stillaguamish River.

Low levees along the Stillaguamish are not capable of protecting this area against more than 45,000 cfs. When the Stillaguamish overtops the dikes

near Silvana or farther downstream, floodwater can enter the city of Stanwood and the Church Creek-Douglas Slough watershed. Conversely, this area is subject to inundation by floodflows originating from the Church Creek-Douglas Slough watershed. Flooding results when the water surface of the Stillaguamish is too high to permit these flows to discharge into the river. Drainage Districts No. 7 and 9 occupy the common flood plain of the Stillaguamish River, Church Creek and Douglas Slough.

## PRESENT AND FUTURE NEEDS

### Evaluation of Present Situation

The 12,600-acre flood plain below Arlington is subject to frequent flooding. This area is a well-developed agricultural community with many farms, residences, and portions of the communities of Stanwood and Silvana. Flood damages begin when the flow of the Stillaguamish River reaches 37,000 cfs at Arlington. Average annual flood damages are estimated to be $256,000. Flooding damages crops, farm lands, farm buildings and equipment, residences, urban developments, roads, railroads, and utilities. The existing levee system was constructed in random, uncoordinated fashion and provides only a low level of flood protection. There are no storage reservoirs to regulate streamflow. Discharges vary widely from a peak of 65,000 cfs in the flood season, to less than 200 cfs in late summer. Beginning several miles above Arlington, bank cutting and sedimentation are major problems along the North and South Forks. Gravel bars obstruct streamflow in many reaches of the main river. Protective works have significantly reduced bank erosion; however, constant maintenance is required and extensive additional works are needed as new areas are eroded. Silt deposited by high and overbank flows in open drainage ditches and outlet channels through the levees, often restricts interior drainage and results in ponding. High tides on Puget Sound also prevent normal drainage for extended periods.

All of the factors mentioned above have an adverse effect on full development and utilization of the flood plain lands.

### Economic Trends

The economy of the Stillaguamish River Basin is partially tied to the economy of the rapidly expanding Seattle, Tacoma, Everett metropolitan area. The major impact this metropolitan area will have on the basin will be the need for more intensive agricultural use of the flood plain lands to supply food needs for the increasing population.

The pattern of the economic growth of the basin in the past has been slower than that of the rest of the Central Division of the Puget Sound Area and this trend is expected to continue in the future. Projections of economic growth for the Central Division have been made for the years 1980, 2000, and 2020 in Appendix IV. Table 5-7 contains a forecast of population, employment, and gross regional product for the Central Division and projects population for the Stillaguamish River Basin. Table 5-8 converts these forecasts into rates of growth and compares these rates to those projected for the United States.

**TABLE 5-7. Economic projections**

| Central Division | 1963 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Population (thousands) | 1,603.0 | 2,418.9 | 3,882.1 | 6,235.5 |
| Employment (thousands) | 579.1 | 873.2 | 1,399.8 | 2,248.4 |
| Gross Regional Product (millions, 1963 dollars) | 5,172.0 | 10,022.0 | 24,569.0 | 62,061.0 |
| Stillaguamish River Basin | | | | |
| Population (thousands) | 17.6 | 30.2 | 48.5 | 77.8 |

**TABLE 5-8. Average annual growth trends (percent)**

| | 1963 To 1980 | 1980 To 2000 | 2000 To 2020 | 1963 To 2020 |
|---|---|---|---|---|
| United States | | | | |
| Population | 1.3 | 1.3 | 1.3 | 1.3 |
| Employment | 1.6 | 1.4 | 1.3 | 1.5 |
| Gross National Product | 4.3 | 3.9 | 4.0 | 4.0 |
| Central Division | | | | |
| Population | 2.4 | 2.4 | 2.4 | 2.4 |
| Employment | 2.4 | 2.4 | 2.4 | 2.4 |
| Gross Regional Product | 3.9 | 4.6 | 4.7 | 4.4 |
| Stillaguamish River Basin | | | | |
| Population | 3.2 | 2.4 | 2.4 | 2.6 |

As seen by an analysis of Table 5-8, the Central Division of the Puget Sound Area will increase at a faster rate than the United States during period 1963 to 2020 in population, employment and Gross Regional Product.

## Land Use Trends

The trend in land use is toward a change of the agricultural lands in the flood plains from a predominantly dairy farming economy to a higher yield berry and vegetable producing economy. There is also some encroachment of urban expansion into the flood plain around the existing communities. In the upper reaches of the river there has been recent widespread construction of summer recreation homes and this trend can be expected to continue.

## Flood Control Needs

**Prevention of Flood Damages**—The community of Stanwood and the agricultural lands in the flood plain need increased flood protection. Average annual damages are estimated to be $256,000 and the damage that would result from a flood with a recurrence interval of 100 years is estimated to be $3,355,000 with most of these flood damages occurring downstream from Arlington.

Based on the methodology and consideration previously discussed for the Puget Sound Area anticipated flood damages in the flood plain of the Stillaguamish River Basin are expected to increase by the percentages as shown in Table 5-9.

**TABLE 5-9. Percentage increase in productivity levels and developments for specified periods**

| Category of Damage | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Agriculture | 29 | 31 | 30 |
| Non-Agriculture | 60 | 110 | 110 |

Application of these percentages to the average annual damages based on 1966 prices and conditions provides an indication of future damages at 1966 prices if additional flood protection is not provided. Table 5-10 shows that the combination of all categories of damage are expected to increase from about $256,000 in 1966 to $1,310,000 by the year 2020.

**TABLE 5-10. Existing and future annual damages (in thousands of dollars)**

| Category | Under Development Levels of 1966 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Agriculture | 100 | 130 | 170 | 220 |
| Buildings & Equipment | 105 | 170 | 350 | 730 |
| Transportation Facilities | 23 | 40 | 80 | 160 |
| Other | 28 | 40 | 90 | 200 |
| Total | 256 | 380 | 690 | 1,310 |

### Optimum Flood Plain Use

**Agriculture**—Portions of the agricultural lands in the flood plain are being encroached upon by urban expansion of Arlington and Stanwood. This encroachment and the increasing food needs for the Seattle metropolitan area will require intensive agricultural utilization of the remaining lands. To meet this required production an increase in the level of flood protection must be provided.

**Recreation**—Recreation in the Stillaguamish Basin is significant. Along the North and South Forks there has been an increasing number of summer home developments which have encroached on flood-prone lands. Further developments can be expected and additional protection must be provided or flood plain regulations initiated to insure that development is consistent with the protection provided.

**Intensive Land Use**—Present intensive land use in the Stillaguamish Basin totals approximately 7,000 acres and is located primarily around the towns of Arlington and Stanwood. The population is projected to increase to 77,800 by the year 2020 resulting in a total of 19,000 acres of land in intensive land use. Additional intensive land use is anticipated to occur around the towns of Stanwood and Arlington.

**Summary of Flood Control Needs**—There is a need to reduce the present flood damages of $256,000 annually that occurs to croplands, buildings, equipment and transportation facilities in the flood plain. The trend of development within the basin is expected to result in the future growth of flood damages approximating 3-1/8 percent compounded annually and will result in future growth of annual damages to $380,000 in 1980, $690,000 in 2000, and $1,310,000 in 2020, if additional protection is not provided.

Additional flood control is needed to reduce the present flood damages and to allow for more intensive utilization of flood plain lands. The existing level of protection of three to five years for agricultural lands should be increased to twenty-five years to provide adequate protection for intensive agriculture. A one-hundred year level of protection should be provided to existing and future developments in the city of Stanwood. The entire Stillaguamish flood plain should be managed to insure that land use is compatible with the degree of flood protection provided.

## MEANS TO SATISFY NEEDS

### Flood Control Objectives

The flood control objectives are to meet the needs set forth in the preceding section by providing flood control through utilization of both structural and nonstructural measures. Objectives of structural measures are shown below in Table 5-11. Nonstructural measures would include a flood plain warning system and flood plain management consistent with the flood protection provided.

**TABLE 5-11. Objectives of structural measures**

| Flood Plain Designation | Levels of Protection[1] 100 Year | 25 Year | 10-15 Year |
|---|---|---|---|
| 300 acres in city of Stanwood | X | | |
| 7,000 acres in the vicinity of Stanwood (North of River) upstream of Silvana | | X | |
| 4,400 acres of agriculturally productive land, Silvana to Arlington | | X | |
| 900 acres of pastureland upstream of Arlington | | | X |

[1] For floods that can be expected to occur on an average of once in the period designated.

### Opportunities for Structural Measures

**Upstream Storage**—An estimated 150,000 acre-feet of flood control storage would be required to provide a 100-year level of flood control in the basin. There are three potential sites on the South Fork and one on the North Fork. The two most promising sites are the Robe on the South Fork and Oso on the North Fork. These two sites could develop about 150,000 acre-feet of effective flood control storage.

**Levees and Channelization**—Flood control by major levee construction would be effective for protection of urban areas in the flood plain adjacent to Stanwood, Arlington, and other towns in the basin. Levees would also be effective in controlling floods in agricultural areas in the flood plain from Arlington downstream to the river's mouth. Channelization improves the flood carrying capacity of the channel and would be effective in the lower Stillaguamish River below Arlington.

### Solutions to Flood Control Needs

**General**—Features of the flood control plan are detailed in Table 5-12 and shown on Figure 5-11. Levees and channel improvements will provide the basis for immediate protection for the flood plain. This protection will allow more intensive use of the flood plain both for agricultural and urban use through the year 2020. Flood plain management is an important part of the flood control plan for the basin. Features of the plan are described as single-purpose flood control. Economic justification may depend on consideration of other water resource needs.

**Sequence of Development**

**1980**—Channel widening and levee construction along 6.2 miles of Hat Slough and the main river, construction of a control weir at the fork of Hat Slough and the Stillaguamish River to hold high flows in the Stillaguamish River within bankful capacity, and construction of a cross levee and a spillway structure north of Stanwood to prevent flooding of Stanwood by Skagit River overflows could provide 100-year protection to the 7,300-acre flood plain area below Silvana. Flood plain regulation should be provided commensurate with the level of flood protection provided.

**1980-2000**—Development in the flood plain between Silvana and Arlington is expected to have developed sufficiently by this period to warrant additional protection. Levees and channelization should be constructed to provide 25-year protection for this area. Flood plain regulations should be continued.

**2000-2020**—By this period it is expected that demand for more intensive use of flood plain lands and developments in the flood plain will have increased to such an extent that additional flood protection will be required. Upstream storage at the

Robe site on the South Fork and at the Oso site on the North Fork may be justified in this period. Flood plain regulation should be continued.

**Economic Analysis for 1980 Level of Flood Control**—The annual benefits and costs for providing the proposed level of protection are given in Table 5-13. Annual costs include interest and amortization of the total investment (including interest during construction) and average annual costs of operation and maintenance of the projects. An interest rate of 4-5/8 percent was used to compute interest during construction and the annual cost of interest and amortization. An economic life of 50 years was used for levee construction. Benefits are based on 1966 prices and include future growth.

**Accomplishments**—Accomplishments of the flood control plan are shown in Table 5-14. One-hundred year protection will be provided to 7,300 acres by the year 1980. Industrial, commercial, and residential developments in the vicinity of Stanwood

**TABLE 5-12. Flood control plan**

| Flood Control Feature | Effective Storage Acre-Feet | River Mile | Height of Dam Feet | Design Capacity cfs | Sequence of Development To 1980 | To 2000 | To 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|---|---|---|---|
| **Levees and Channelization** | | | | | | | | |
| Levees and channel improvements to protect Stanwood and the Flood Plain upstream to Silvana | | | | 93,000 | X | | | $ 7,700,000 |
| Silvana upstream to Arlington | | | | 73,000 | | X | | 3,700,000 |
| **Flood Control Storage Projects** | | | | | | | | |
| North Fork (Oso) | 80,000 | 2.1 | 200 | | | | X | 25,100,000 |
| South Fork (Robe) | 70,000 | 24 | 240 | | | | X | 21,200,000 |
| **Flood Plain Management** | | | | | X | X | X | 2,000[1] |
| | | | | Total Cost of Plan | | | | $57,702,000 |

[1] Snohomish County and State of Washington implementation costs only. Cost of the completed Flood Plain Information Study is not included.

**TABLE 5-13. Estimated costs and benefits for projects to be constructed prior to 1980**

| Project | Estimated[3] Total Construction Costs | Estimated[3] Annual Cost | Estimated Annual Flood Damage Prevention Benefits | Estimated Annual Land Enhancement Benefits | Total Annual Benefits |
|---|---|---|---|---|---|
| *Protection from rivers mouth upstream to Silvana* | $7,700,000 | $454,000 | $238,000 | $262,000 | $500,000 |
| Flood Plain Management | -- | 2,300[1] | 53,000[2] | -- | 53,000 |
| Total | $7,700,000 | $456,300 | $291,000 | $262,000 | $553,000 |

[1] Includes Federal, Snohomish County and State of Washington administration and enforcement costs.

[2] Based on reduction of future flood damages in the building and equipment category.

[3] 1968 price level.

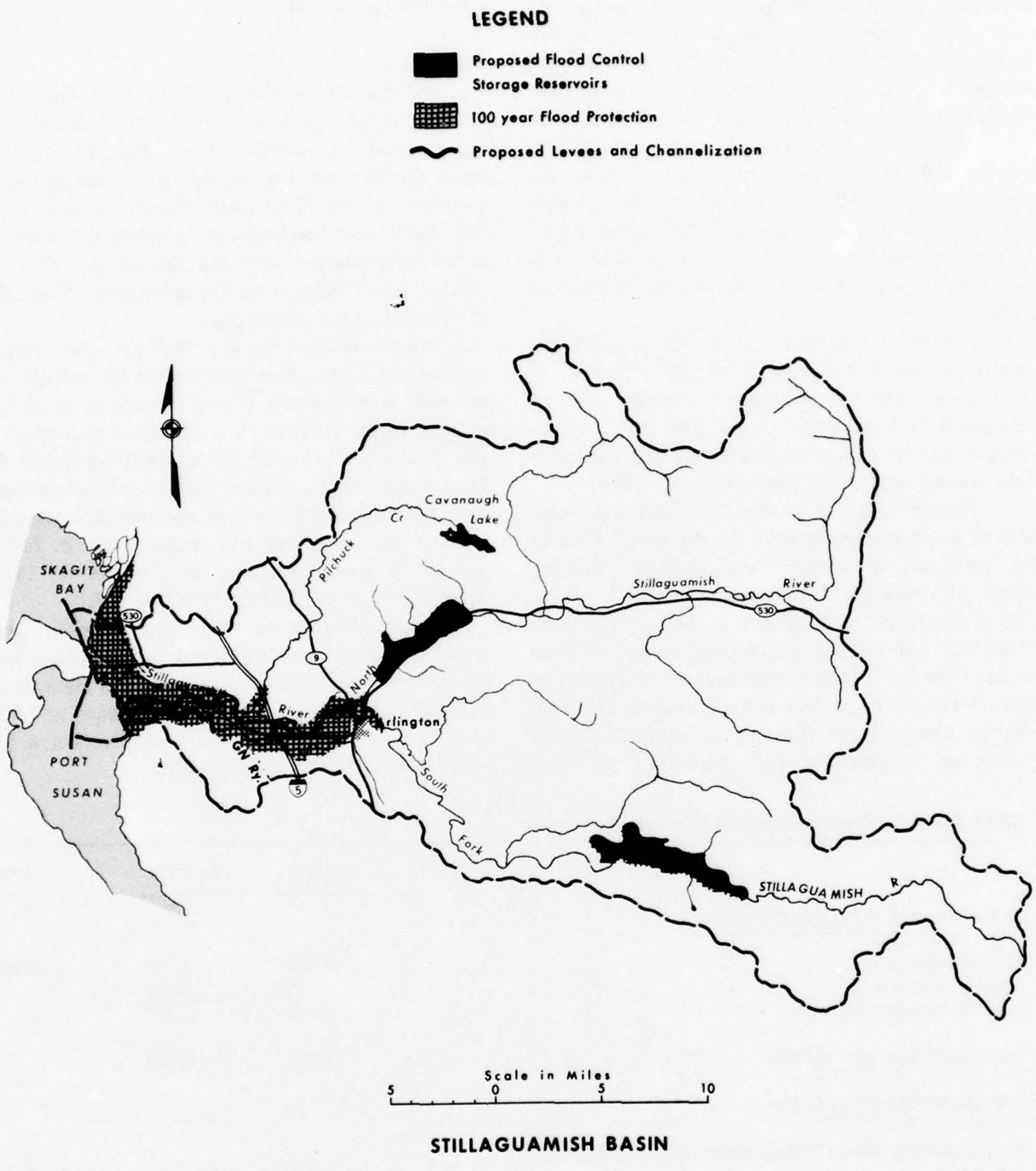



FIGURE 5-11. Proposed flood control plan and accomplishments

will be provided adequate protection and expansion of these facilities can be expected. Twenty-five year protection would be provided to 4,400 acres by the year 2000. Upstream storage constructed on the North and South Forks would provide protection in excess of 100 years for the entire flood plain below the damsites in the 2000-2020 period.

**Alternatives Considered**–Upstream flood control storage on the North and South Forks was considered as an alternative to the levee and channel improvements along the lower Stillaguamish River. This alternative was found to be more costly and economically infeasible for development by the year 1980.

Permanent evacuation of the flood plain was considered but determined infeasible. Purchase of flood plain lands and relocation of existing developments and facilities would be required. Major relocations would be excessively expensive and unacceptable to a majority of the residents in the valley.

Floodproofing of existing buildings was evaluated as an alternative to major flood protective works for reduction of present flood damages. Existing urban and industrial developments in the communities of Stanwood and Silvana as well as numerous residences and associated buildings located in rural areas of the flood plain would require floodproofing. Approximately 40 percent of the estimated $256,000 average annual flood damages or about $100,000 occurs to buildings. A high percentage of these buildings are wood frame construction and floodproofing would require structural treatment that is economically infeasible.

## Summary

In the 12,600-acre flood plain of the Stillaguamish River, the towns of Stanwood and Silvana are exposed to excessive flood hazards. Existing levees provide only a three-year level of protection to a portion of the flood plain. Floods damage crops, farm lands, farm buildings and equipment, residences, urban developments, roads and railroads, and utilities. Annual flood damages are estimated to be $256,000 at 1966 prices and conditions.

Flood damage studies indicate that future average annual flood damages could be expected to increase in proportion to the increase in economic activity in the flood plain if additional protection is not provided. The trend of development within the basin could result in future growth of flood damages approximating 3-1/8 percent compounded annually without flood control and could result in future growth of annual damages to $380,000 in 1980, $690,000 in 2000, and $1,310,000 in 2020.

Implementation of the flood control plan would significantly reduce flood plain damages and permit optimum utilization of the flood plain. One-hundred year protection would be provided to 7,300 acres by 1980 and to the entire flood plain below the town of Arlington by the year 2020.

**TABLE 5-14. Accomplishments of flood control plan**

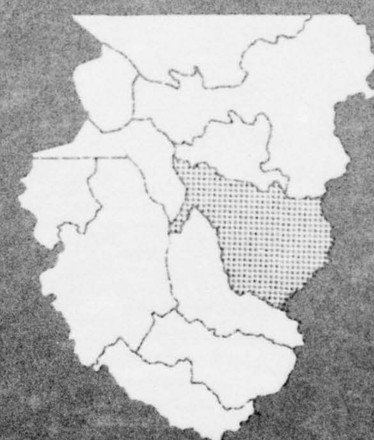
| | To 1980 | To 2000 | To 2020 |
|---|---|---|---|
| Acreage Protected by Structural Measures | | | |
| 100 year protection | 7,300 | 7,300 | 12,600 |
| 25 year protection | 0 | 4,400 | -- |
| Less than 15 year protection | 5,300 | 900 | -- |
| Flood Plain Management (Acres) | 5,300 | 5,300 | -- |
| Flood Damage Prevention (Dollars) | | | |
| Projected average annual flood damages without additional protection | $380,000 | $690,000 | $1,310,000 |
| Reduction in future average annual flood damages due to flood plain management | $ 33,000 | $123,000 | $ 313,000 |
| Projected residual average annual flood damages with flood plain management | $347,000 | $567,000 | $ 997,000 |
| Reduction in future average annual flood damages with implementation of structural measures | $160,000 | $373,000 | $ 967,000 |
| Projected residual average annual flood damages | $187,000 | $194,000 | $ 30,000 |

# Whidbey-Camano Islands

# WHIDBEY — CAMANO ISLANDS

There are no large streams or rivers in the Whidbey-Camano Islands and overbank flooding is not considered a serious problem. Small watershed flooding and ponding problems in the Islands are discussed in Appendix XIV, Watershed Management.

# Snohomish Basin



# SNOHOMISH BASIN

## DESCRIPTION OF BASIN

The Snohomish Basin includes 1,903 square miles of land and inland waters in Snohomish and King Counties in northwestern Washington. The basin, Figure 7-1, is bounded by the Stillaguamish and Skagit River Basins on the north, the Sammamish and Cedar River Basins on the south, the crest of the Cascade Range on the east, and Puget Sound on the west. Elevations decrease from 7,000 feet in the Cascade Mountains to sea level at Possession Sound, an arm of Puget Sound. In the eastern half of the basin, stream valleys are narrow and flanked by rugged mountains and foothills. In the downstream 19 miles of the Skykomish and 35 miles of the Snoqualmie Rivers, the valleys widen and the surrounding hills decrease in elevation. Below the junction of these streams, the Snohomish valley is from 1 to 3 miles wide and has a very flat gradient. Marshes and tidal lowlands are found along the lower reaches of the river. Stream and water surface profiles are shown in Figures 7-2 and 7-3.

Soils of the mountainous areas in the eastern part of the watershed consist of shallow mantles of loams, stony and rocky loams overlying bedrock of limestone, basalt, slate, shale, schist, gneiss, granite and quartzite. Soils of the western part of the basin were formed in cemented sandy glacial till, glacial clay till and outwash glacial sands and gravels. Their textures are loams, clay loams, sandy loams, gravelly sandy loams, sands and gravelly sands. The flood plains consist of sands and gravelly sands in the upper reaches and become progressively finer textured to fine sandy loams, silt loams, loams, clay loams and silty clay loams in the lower reaches. Peat and mucks occur in many small drainage basins.

Maritime air influences both precipitation and temperatures in the Snohomish Basin, producing a mild, wet climate. The mean temperature is 50°F. in the lower basin, and 43°F in the mountainous regions. Average annual precipitation is 197.6 inches at Snoqualmie Pass and 35.2 inches at Everett. In the higher elevations, the heavy winter snowpack usually remains intact until late spring or early summer. The average annual snowfall at Snoqualmie Pass is 420 inches but drops to only eleven inches at Everett.

Natural resources of the Snohomish Basin include high quality water, fertile agricultural lands, timber, and anadromous fish. Abundant water supply has influenced the past growth of the basin and will continue to play a major role in shaping future developments. Productive agricultural lands along the rivers are under intensive cultivation. The fish resource is an important means of livelihood for commercial fishermen and provides high quality recreation for sport fishermen. Timber continues to be an important resource. Forests cover about two million acres of King and Snohomish Counties. Over four-fifths of the timberland is in commercial forests, of which 980,000 or 60% is classified as sawtimber. The wood product industry imports logs from other areas to supplement that harvested within the basin.

Port and transportation facilities adequately support a thriving industrial-agricultural economy. Everett Harbor serves the Everett metropolitan area. Port Gardner and the East Waterway have a navigation channel 30 feet deep and terminal facilities for ocean going vessels. The 15-foot-deep inner harbor accommodates pleasure crafts and tugboats with barge and log tows, and contains log storage areas. The entire length of the Snohomish River is navigable by light craft. Photograph 7-1 shows the river mouth at Everett. Interstate Highway 5, U.S. Highways 99 and 2, and three transcontinental railroads cross the basin at Everett.

Current population of the Snohomish Basin is about 197,000 of which only 2.3% live in the flood plain. Principal towns and their 1967 population are shown in Table 7-1. The importance of the Snohomish Basin is due to proximity to the Seattle metropolitan area which has the highest population density in the Puget Sound region. About 63.5% of the people in the twelve Puget Sound counties live in King or Snohomish County. Residents commuting from one county to work in another county is a common occurrence. Intensive land use is expected due to the very high population surrounding the flood plains of this river system.

TABLE 7-1. Population—past and present

| Area | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| United States (thousands) | 132,164 | 151,326 | 179,323 | 200,100 | 52 |
| Puget Sound (thousands) | 1,007 | 1,418 | 1,768 | 2,100 | 105 |
| Central Division (thousands) | 820 | 1,196 | 1,513 | 1,751.2 | 114 |
| Snohomish County (thousands) | 88.8 | 111.6 | 172.2 | 224.4 | 153 |
| Snohomish Basin (thousands) | 84.0 | 107.0 | 162.0 | 201.3 | 140 |
| Cities and towns in the Basin | | | | | |
| Snoqualmie | 780 | 810 | 1,220 | 1,230 | 59 |
| North Bend | 650 | 790 | 950 | 1,210 | 87 |
| Everett | 30,220 | 33,850 | 40,300 | 52,000 | 72 |
| Snohomish | 2,790 | 3,090 | 3,890 | 4,700 | 68 |
| Monroe | 1,590 | 1,560 | 1,900 | 2,200 | 38 |

Figures are from U.S. Census Report, Seattle Area Industrial Council, 1967, and Appendix IV, Economics.

TABLE 7-2. Employment—past and present

| Industry | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| Agriculture | 10,350 | 9,400 | 7,180 | 7,960 | -23 |
| Forestry, Fishing, Mining | 3,340 | 3,330 | 1,770 | 2,450 | -28 |
| Contract Constr. | 13,350 | 23,130 | 25,410 | 30,700 | 130 |
| Manufacturing (Total) | (47,360) | (67,700) | (116,830) | (182,320) | (285) |
| Food & Kindred Prod. | 6,640 | 8,110 | 10,180 | 10,200 | |
| Lumber, Wood & Furn. | 13,670 | 13,030 | 11,450 | 9,500 | |
| Paper & Allied Prod. | 1,850 | 3,200 | 4,240 | 4,400 | |
| Chem. & Allied Prod. | 950 | 1,390 | 1,570 | 1,200 | |
| Fabricated Metal | N.A. | 3,540 | 5,760 | 5,600 | |
| Mach. (Elec. & Non Elec.) | 1,940 | 3,682 | 6,940 | 9,700 | |
| Transp. Equipment | 9,090 | 20,700 | 57,670 | 108,100 | |
| Primary Metal | N.A. | 2,910 | 2,630 | 2,900 | |
| All Other | 13,230 | 11,140 | 14,460 | 30,720 | |
| Non-Commodity Industry | 144,600 | 215,350 | 268,750 | 364,470 | 152 |
| Total Employment | 219,100 | 318,910 | 419,930 | 587,900 | 168 |

PHOTO 7-1. Mouth of Snohomish River and distributaries. The Great Northern Railroad and Interstate Highway 5 cross the river mouth and agricultural lands. Log rafts await processing at plywood and paper mills.

The economic base of the Snohomish Basin is interrelated with centers of population commerce, and industries contiguous to the basin. This economic activity is located predominently in King and Snohomish Counties. This includes the metropolitan Seattle area centered in King County which is currently experiencing an urban and industrial growth rate greater than the United States as a whole. Employment statistics for the basin and the basin environment are best demonstrated by the combination of information for King and Snohomish Counties. Table 7-2 presents historical and estimated present employment by major employment sectors.

As shown in the above table, employment activity in the basin and contiguous environment has been based primarily on forest and agricultural industries. In 1940, the manufacture of lumber and

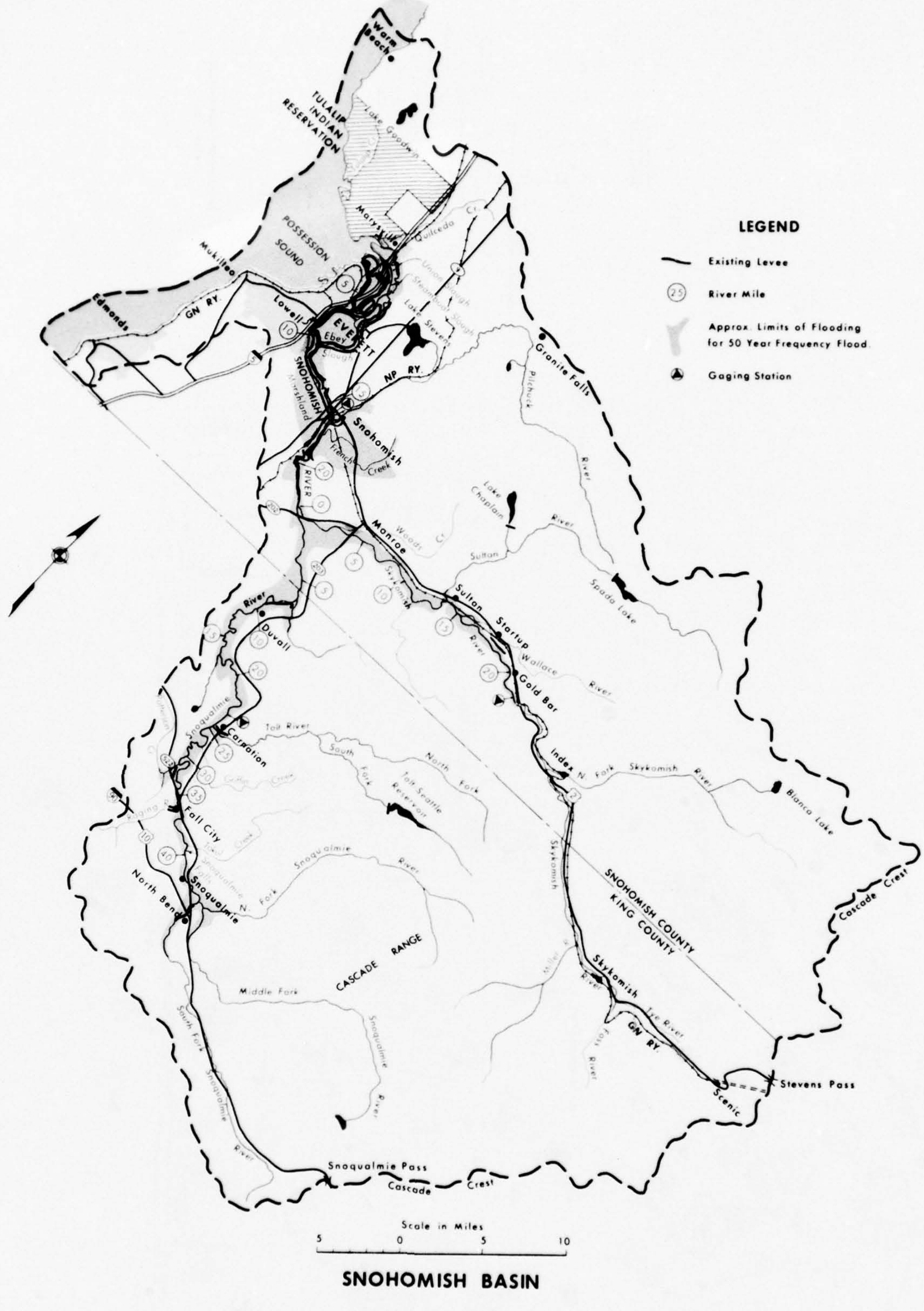
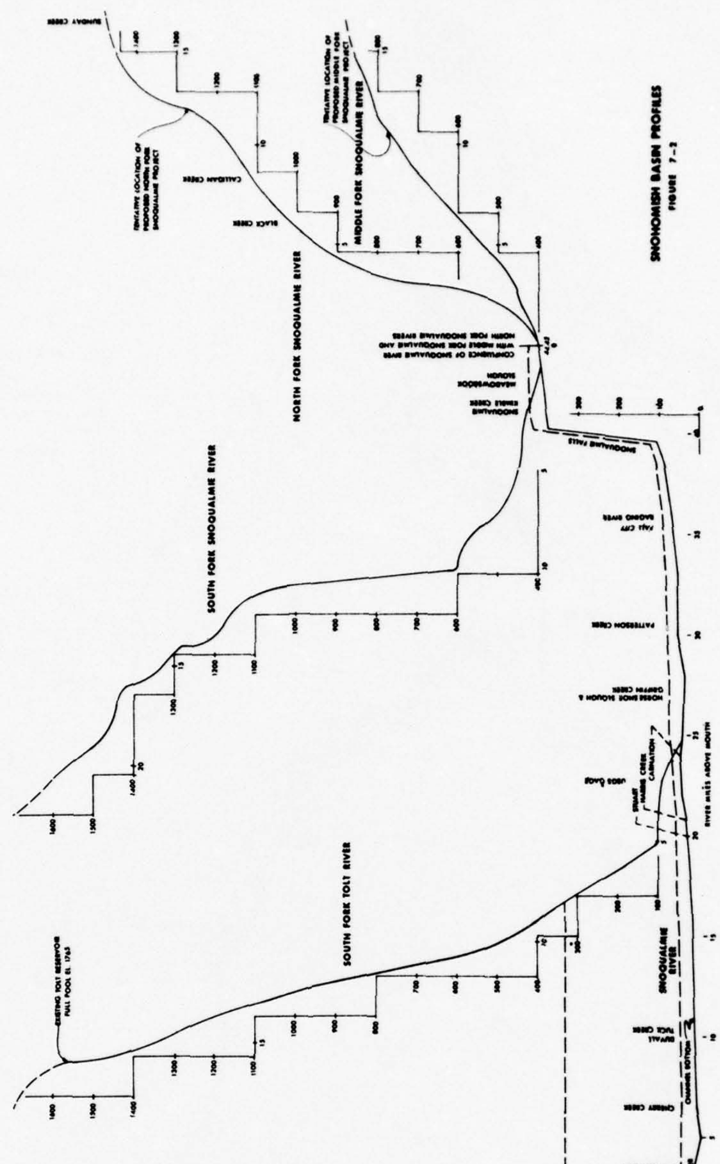
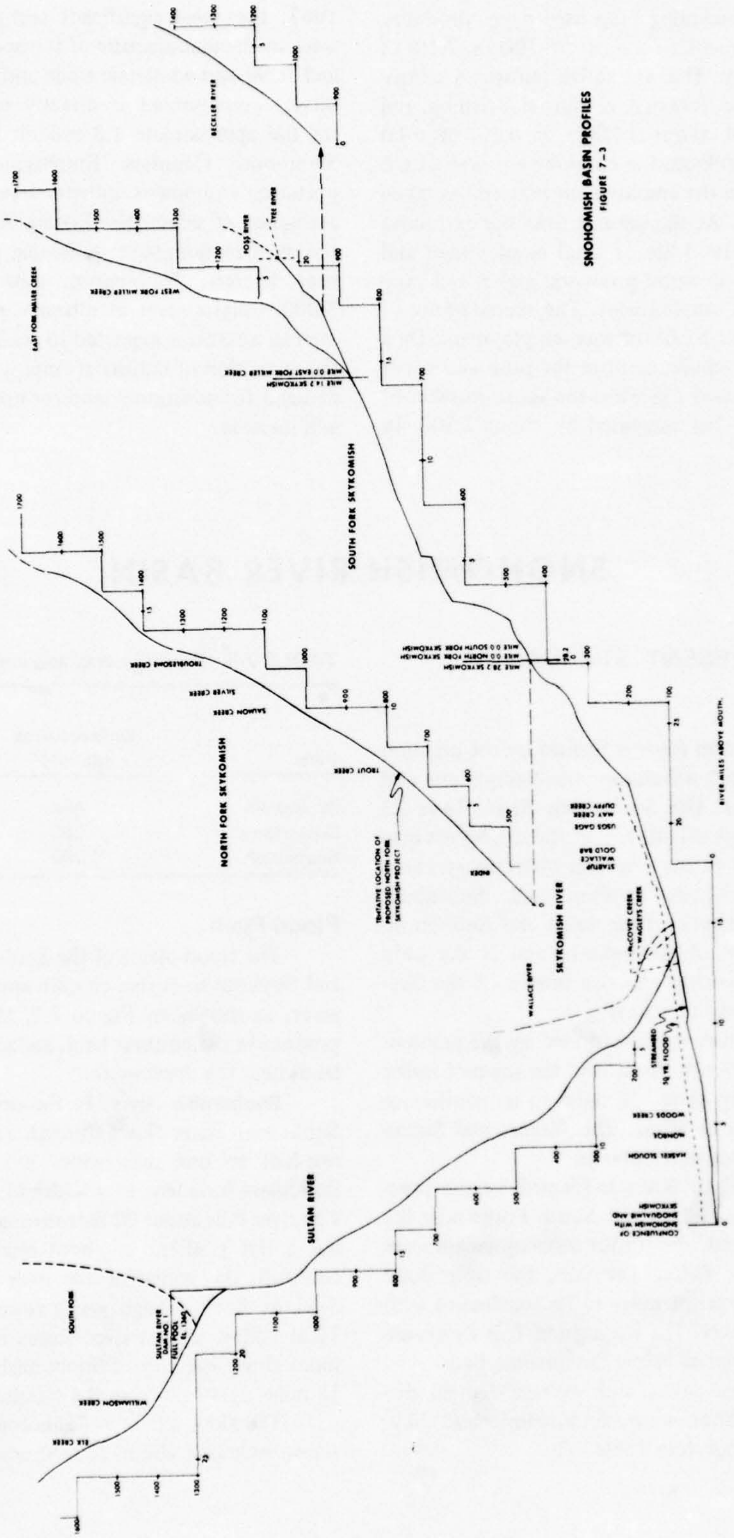



**FIGURE 7-1. Flood plain and existing protective works**




SNOHOMISH BASIN PROFILES

FIGURE 7-2




SNOHOMISH BASIN PROFILES
FIGURE 7-3

wood products, including pulp used paper products, provided employment to almost 15,500 or 7.1% of total employment. The extractive industries consisting of agriculture, forestry, commercial fishing, and mining, employed about 14,000 or 6.2% of total employment. Manufacturing employment was 21.6% in 1940. A shift in the employment pattern has taken place since 1940. At the present time the extractive industries constitute 1.8% of total employment and the manufacture of wood products, paper, and pulp are 3.4% of total employment. The manufacture of all products is now 31.0% of total employment. On a percentage basis, employment in the pulp and paper industry has increased 138% but the actual number of people employed has increased by about 2,500. In 1967, the most significant sectors of employment were in the manufacture of transportation equipment and retail and wholesale trade and services. Trade and service employment is directly related to providing for the approximate 1.3 million people in King and Snohomish Counties. Employment in the transportation equipment industry is largely in the field of aerospace of which the Boeing Aircraft Company is the most predominant. A Boeing plant at Paine Field near Everett, Washington, now employees about 5,000. Employment at ultimate production of commercial aircraft is expected to reach about 15,000. As the expansion of industrial employment increases, the demand for additional land for urban use in the basin will increase.

# SNOHOMISH RIVER BASIN

## PRESENT STATUS

### Stream System

The Snohomish River is formed by the junction of its two principal tributaries, the Snoqualmie and Skykomish Rivers. The Snohomish River flows 23 miles in a northwesterly direction and discharges into Possession Sound through several distributary channels, principally Ebey, Union, and Steamboat Sloughs. The Pilchuck River joins the Snohomish River at the city of Snohomish, and is the only sizeable tributary below the confluence of the Skykomish and Snoqualmie Rivers.

The Skykomish River is formed by the junction of its North and South Forks near the town of Index and flows westerly about 28 miles to its confluence with the Snoqualmie River. The Wallace and Sultan Rivers are the principal tributaries.

The Snoqualmie River is formed by the junction of its North, Middle and South Forks near the town of North Bend, about four miles upstream from Snoqualmie Falls. Below the falls, the river flows northwesterly about 36 miles to its confluence with the Skykomish River. The Raging and Tolt Rivers are the principal tributaries below Snoqualmie Falls.

The drainage areas and average annual discharges of the Snohomish, Snoqualmie and Skykomish Rivers are given in Table 7-3.

**TABLE 7-3. Drainage area and average annual runoff**

| River | Drainage Area (sq. mi.) | Average Annual Runoff (acre-feet) |
|---|---|---|
| Skykomish | 844 | 3,469,000 |
| Snoqualmie | 693 | 3,251,000 |
| Snohomish | 1,780 | 7,090,000 |

### Flood Plain

The flood plains of the Snohomish, Snoqualmie and Skykomish Rivers contain approximately 59,000 acres, as shown on Figure 7-1. Most of this area is productive agricultural land, including reclaimed tidelands near the rivermouth.

**Snohomish River.** In the upper four miles, the Snohomish River flows through a narrow valley from one-half to one mile wide. Below this reach, the floodplain broadens to a width of two to three miles. The river falls about 22 feet throughout its length and has a flat gradient of about one foot per mile. At bankfull, the width of the river channel above the head of Ebey Slough varies from 350 to 500 feet. Tidal action affects river stages to a point about 3 miles above the city of Snohomish, or approximately 18 miles upstream from the mouth.

The flood plain contains approximately 25,000 acres, including about 18,000 acres of highly devel-

oped farmlands. Low levees protect these lands against high tides on Puget Sound and two to four-year frequency winter floods. Levees along the Snohomish River and its distributary channels constrict the area available to carry floodflows. As a result, high river stages occur more frequently.

Developments in the flood plain include well maintained dwellings and farm buildings, highways, utilities and railroads. Urban, suburban and industrial developments adjacent to the cities of Snohomish, Marysville and Everett extend onto the flood plain. Interstate Highway 5, U.S. Highway 2, and State Highways 9 and 202, and three transcontinental railroads cross the flood plain.

Twelve bridges cross the distributary channels of the Snohomish River: three on the main river, five on Ebey Slough, two on Steamboat Slough, and two on Union Slough. Three highway bridges and two railroad bridges cross the Snohomish River upstream from the distributary channels.

**Snoqualmie River.** The flood plain of the Snoqualmie River contains about 23,000 acres. Below Snoqualmie Falls, the flood plain averages approximately 1 mile in width and contains fertile but frequently flooded farmlands. Communities along this reach include Duvall on the right bank approximately 10 miles above the rivermouth, Carnation on the right bank approximately 24 miles above the rivermouth, and Fall City on the left bank approximately 36 miles above the rivermouth. Part of the town of Carnation is on the flood plain. The Tolt River flows into the Snoqualmie River near Carnation. Five bridges on county roads and one on State Highway 203 span the river in the reach below Snoqualmie Falls. Above Snoqualmie Falls, the flood plain extends up the South Fork about 4 miles, up the Middle fork about 5 miles, and up the North Fork about 3 miles. The rapidly growing urban communities of Snoqualmie and North Bend, in the upper flood plain, are subject to large and frequent flood damages. Three State Highway bridges, two Northern Pacific Railroad bridges, and five county bridges span the Snoqualmie River above Snoqualmie.

**Skykomish River.** The Skykomish River flood plain contains approximately 11,000 acres. The North and South Forks of the river system rise in rugged, mountainous terrain and flow through steep, narrow canyons. The Skykomish valley is about 24 miles long and one mile wide. The stream has a steeper gradient than the Snoqualmie River and its channel is poorly defined, braided and shallow. The towns of Monroe, Sultan and Gold Bar are on the right bank of the Skykomish, about 4, 14 and 20 miles, respectively, above the rivermouth. The town of Index is on the right bank of the North Fork, about one mile above its mouth. The town of Startup is on the right bank of the Wallace River, about 3 miles above its junction with the Skykomish River, near Sultan. All of these communities are partially within the flood plain. Bridges span the Skykomish River on a county road at river mile 14.0, on U.S. Highway 2 at river mile 22.9, and on the mainline of the Great Northern Railroad at river mile 22.5. The Sultan River joins the Skykomish River at the town of Sultan.

PHOTO 7-2. Flooded buildings on the left river bank, downstream from the town of Snohomish, 20 November 1962.

## History of Flooding

**Flood Characteristics.** Topographic and climatic conditions of the Snohomish River drainage area are typical of the Puget Sound Area. Two high water periods usually occur each year. In the late fall or winter, floods are caused by rainstorms originating from the Pacific Ocean. Intense precipitation accompanied by warm winds rapidly melts the accumulated snowpack. These storms usually last two to three days, and river discharges may increase from a relatively low base flow to near flood stage within a few hours. In the spring or early summer, high water results from rising temperatures and snowmelt in the higher elevations, and is characterized by large-volume flows with relatively low crests. Rain storms in May or June cause sharp rises of short duration.

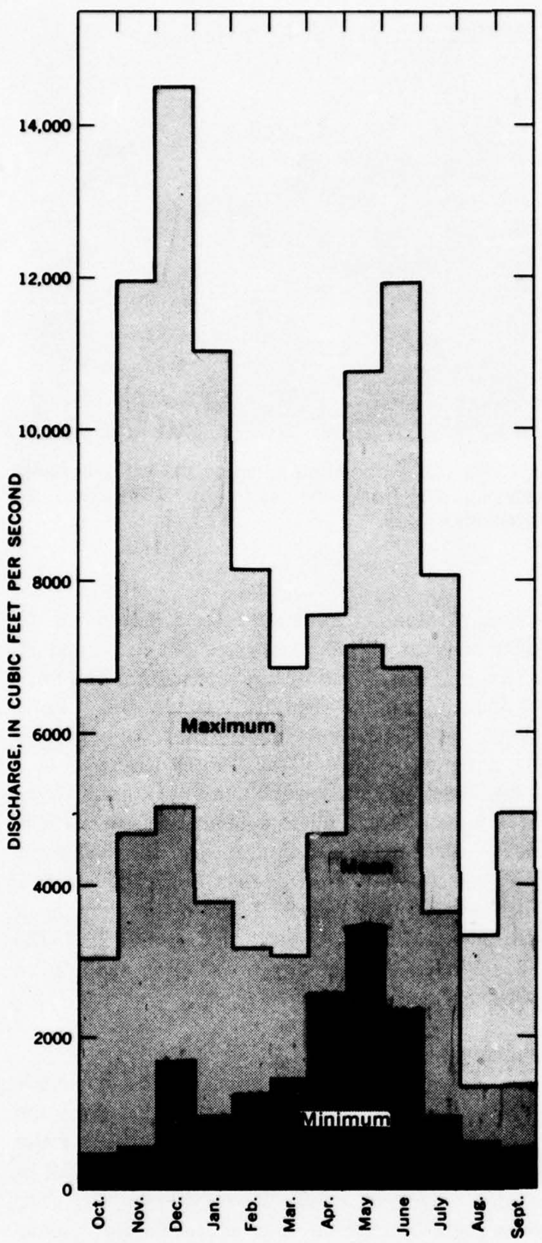



FIGURE 7-4. Maximum, mean and minimum monthly discharges, Skykomish River near Gold Bar, 1931-60.

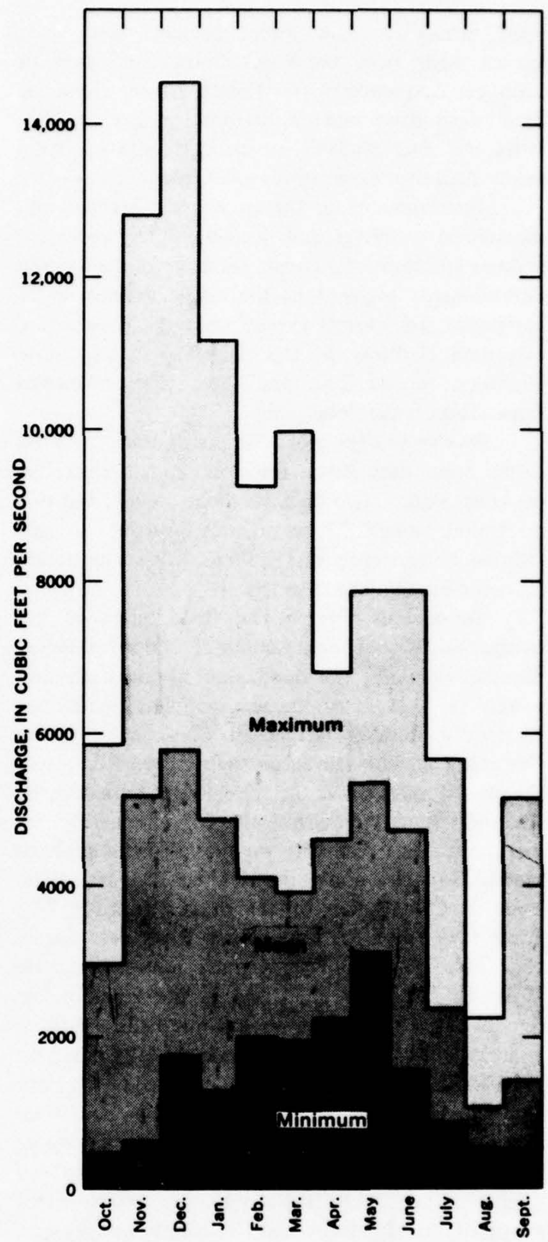



FIGURE 7-5. Maximum, mean and minimum monthly discharges, Snoqualmie River near Carnation, 1931-60.

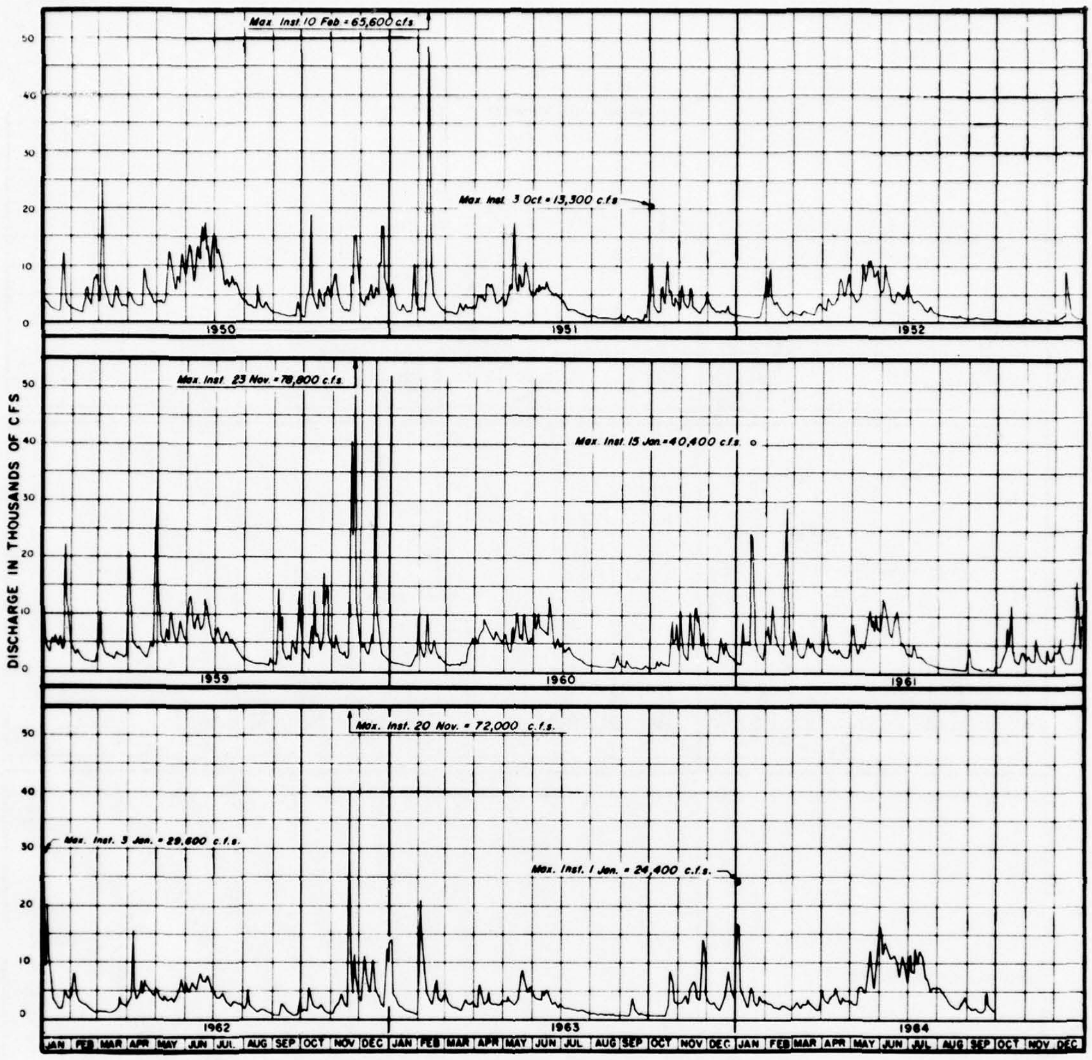



**FIGURE 7-6. Daily discharge hydrograph, Skykomish River near Gold Bar.**

The monthly discharge graphs, Figures 7-4 and 7-5, and the daily discharge hydrographs, Figures 7-6 and 7-7, show the runoff pattern for the Skykomish River near Gold Bar and the Snoqualmie River near Carnation.

Streamflow characteristics on the Skykomish River near Gold Bar and on the Snoqualmie River near Carnation are typical of the Snohomish River. Mean flows decrease to approximately 1,500 cfs on the Skykomish and 1,000 cfs on the Snoqualmie in August and September. Thereafter, the flows begin to increase and can reach peak discharges about 50 times greater than the mean flows during winter floods.

**Floods.** Streamflow records in the Snohomish Basin have been maintained since 1898, when the first gage was established on the Snoqualmie River near Snoqualmie. Of 51 stations established, 23 are currently operating. Stream gaging stations on the

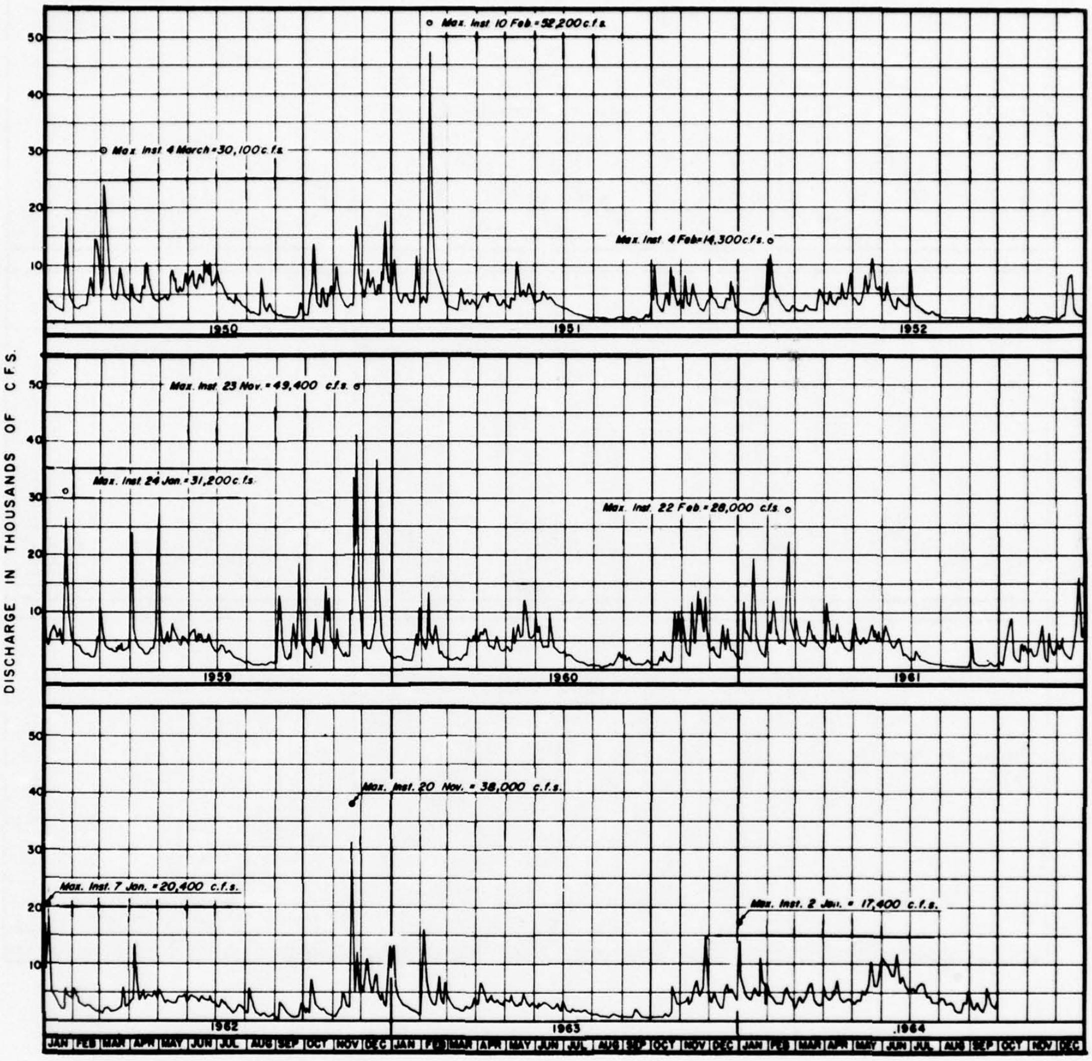



**FIGURE 7-7. Daily discharge hydrograph, Snoqualmie River near Carnation.**

Skykomish near Gold Bar and the Snoqualmie near Carnation jointly measure drainage from 1,138 square miles as compared to 1,714 square miles measured by the Snohomish River gage at Snohomish, and offer the best index of mean runoff conditions in the basin. Records at these two stations show that the average annual runoff for the period 1931-1960 is approximately 93 inches over the 1,138 square mile drainage area. This area represents 64% of the entire basin, but contributes approximately 82% of the total runoff.

The gage on the Snohomish River at Snohomish has been used to measure flood discharges since 1941. Because of tidal fluctuations, low flow records cannot be obtained. Low flow records are available from a gaging station on the Snohomish River near Monroe, since February 1963; however, the period of record is too short for use in this report.

Zero damage flow is estimated to be 43,000 cfs for the Snohomish River near Snohomish, 40,000 cfs for the Skykomish River near Gold Bar, and 22,600 cfs for the Snoqualmie River near Carnation. The zero damage flow has been exceeded at least 31 times on the Skykomish since 1928, 56 times on the Snoqualmie since 1929, and 55 times on the Snohomish since 1942, as shown in Table 7-4.

**TABLE 7-4. Peak discharges greater than zero damage**

| Discharge cfs | Date | Discharge cfs | Date |
|---|---|---|---|
| | **Skykomish River** | | |
| 88,700 | 21 Dec 1933 | 47,200 | 18 Apr 1938 |
| 83,300 | 26 Feb 1932 | 46,900 | 11 Dec 1955 |
| 78,800 | 23 Nov 1959 | 46,500 | 4 Nov 1955 |
| 78,600 | 15 Dec 1959 | 45,300 | 19 Oct 1949 |
| 72,500 | 13 Nov 1932 | 44,500 | 2 Dec 1932 |
| 72,000 | 20 Nov 1962 | 42,100 | 12 Nov 1958 |
| 71,600 | 3 Dec 1943 | 41,700 | 23 Oct 1933 |
| 65,600 | 10 Feb 1951 | 40,800 | 29 Apr 1959 |
| 62,400 | 24 Oct 1934 | 40,600 | 31 Jan 1953 |
| 59,100 | 10 Dec 1956 | 40,500 | 23 Jan 1953 |
| 56,500 | 27 Nov 1949 | 40,400 | 15 Jan 1961 |
| 55,800 | 2 Nov 1933 | 40,300 | 5 Nov 1934 |
| 55,800 | 24 Jan 1935 | 40,300 | 7 Feb 1945 |
| 54,800 | 29 Nov 1959 | 40,200 | 11 Dec 1956 |
| 48,100 | 17 Nov 1932 | 40,000 | 2 Dec 1958 |
| 47,400 | 7 Jan 1945 | | |
| | **Snoqualmie River** | | |
| 59,500 | 27 Feb 1932 | 30,300 | 24 Nov 1942 |
| 59,000 | 13 Nov 1932 | 30,100 | 4 Mar 1950 |
| | **Snoqualmie River (Cont.)** | | |
| 52,200 | 10 Feb 1951 | 30,000 | 10 Dec 1956 |
| 49,400 | 23 Nov 1959 | 29,900 | 1 Nov 1942 |
| 49,200 | 15 Dec 1959 | 29,500 | 24 Oct 1933 |
| 48,700 | 3 Nov 1933 | 29,400 | 13 Nov 1958 |
| 48,400 | 3 Dec 1943 | 29,300 | 18 Dec 1933 |
| 47,800 | 10 Dec 1933 | 29,100 | 28 Nov 1937 |
| 47,100 | 25 Oct 1934 | 29,100 | 24 Jan 1947 |
| 45,500 | 3 Dec 1932 | 28,100 | 30 Apr 1959 |
| 41,600 | 29 Jan 1965 | 28,000 | 22 Feb 1961 |
| 41,400 | 8 Jan 1933 | 27,400 | 28 Jan 1931 |
| 40,800 | 12 Dec 1955 | 26,800 | 21 Nov 1958 |
| 40,800 | 22 Dec 1933 | 25,500 | 2 Apr 1959 |
| 38,800 | 18 Apr 1938 | 25,300 | 8 Feb 1955 |
| 37,800 | 20 Nov 1962 | 24,800 | 19 Oct 1947 |
| 37,400 | 25 Jan 1935 | 24,800 | 8 Nov 1947 |
| 37,300 | 21 Nov 1959 | 24,600 | 5 Nov 1955 |
| 35,700 | 10 Dec 1953 | 24,200 | 6 Nov 1934 |
| 35,000 | 12 Jan 1932 | 24,000 | 8 Feb 1945 |
| 34,000 | 6 Mar 1932 | 23,800 | 12 Jan 1953 |
| 33,900 | 2 Dec 1965 | 23,700 | 9 Nov 1937 |
| 32,600 | 23 Jan 1934 | 23,600 | 19 Mar 1932 |
| 32,600 | 11 Dec 1946 | 23,600 | 6 Nov 1932 |
| 32,400 | 1 Feb 1953 | 23,500 | 26 Oct 1945 |
| 32,200 | 24 Jan 1953 | 23,100 | 6 Dec 1933 |
| 32,000 | 8 Jan 1945 | 23,100 | 27 Nov 1949 |
| 31,200 | 24 Jan 1959 | 22,900 | 8 Dec 1938 |
| | **Snohomish River** | | |
| 136,000 | 10 Feb 1951 | 55,800 | 25 Oct 1945 |
| 113,300 | 23 Nov 1959 | 54,800 | 8 Feb 1955 |
| 70,000 | 15 Dec 1946 | 54,500 | 26 Oct 1955 |
| 67,800 | 30 Jan 1965 | 54,200 | 4 Jan 1962 |
| 67,000 | 27 Nov 1949 | 54,000 | 10 Dec 1953 |
| 66,900 | 29 Nov 1962 | 53,100 | 28 Dec 1949 |
| 65,800 | 23 Jan 1953 | 52,800 | 16 Dec 1956 |
| 64,600 | 3 Dec 1943 | 51,000 | 12 Dec 1953 |
| 63,400 | 1 Feb 1953 | 50,200 | 6 Dec 1944 |
| 61,000 | 7 Jan 1945 | 49,000 | 25 Dec 1950 |
| 60,500 | 21 Feb 1961 | 49,000 | 1 Jan 1964 |
| 60,500 | 25 Oct 1946 | 48,700 | 1 Nov 1942 |
| 60,000 | 12 Jan 1953 | 48,600 | 4 Feb 1963 |
| 59,800 | 29, Apr 1959 | 48,200 | 10 Jan 1953 |
| 59,600 | 2 Dec 1965 | 47,700 | 29 May 1948 |
| 59,000 | 10 Dec 1956 | 47,300 | 13 Jan 1945 |
| 58,700 | 19 Oct 1947 | 47,000 | 15 Jun 1946 |
| 58,600 | 4 Nov 1955 | 46,700 | 28 Mar 1943 |
| 58,500 | 4 Mar 1950 | 46,700 | 22 Jan 1950 |
| 58,200 | 12 Nov 1958 | 46,500 | 10 Nov 1955 |
| 57,200 | 24 Jan 1947 | 45,500 | 26 Nov 1950 |
| 57,200 | 12 Dec 1955 | 45,000 | 27 Nov 1963 |
| 57,200 | 8 Jan 1962 | 44,500 | 1 Nov 1953 |
| 57,000 | 24 Jan 1959 | 44,000 | 24 Nov 1948 |
| 56,600 | 24 Nov 1942 | 43,600 | 10 Oct 1950 |
| 56,500 | 2 Apr 1959 | 43,500 | 18 Nov 1954 |
| 56,300 | 16 Jan 1961 | 43,100 | 16 Oct 1956 |
| 56,200 | 21 Nov 1958 | | |

PHOTO 7-3. Flooded industrial and agricultural lands on the Snohomish River at approximately river mile 9. View is upstream toward the town of Snohomish (Nov. 1959 flood).

PHOTO 7-4. Snohomish River flood plain at town of Snohomish during November 1959 flood. View is upstream.

Table 7-5 lists the peak discharges and recurrence intervals of recent major floods and projected 50 and 100 year floods at Snohomish. Estimated flood damages are based on 1966 prices and conditions.

**TABLE 7-5. Major floods and estimated damages**

| Date or Frequency | Peak Discharge at Snohomish cfs | Average Recurrence Interval (years) | Current Estimated Damages |
|---|---|---|---|
| 10 Feb 1951 | 136,000 | 87 | $ 7,980,000* |
| 23 Nov 1959 | 113,300 | 28 | $ 6,730,000 |
| 50 year | 124,000 | 50 | $10,760,000 |
| 100 year | 139,000 | 100 | $16,980,000 |

* The peak flood discharge on the Snoqualmie River was 42,200 cfs, an estimated recurrence interval of about once in 15 years.

The floods of February 1951 and November 1959 were the result of intense winter storms. Photos 7-3 and 7-4 above show some of the flooding that occurred during the November 1959 flood. The 1951 flood had a maximum recorded flow at Snohomish of 136,000 cfs and inundated about 35,000 acres of agricultural land. The width of the flooded area varied from one-fourth mile to 3 miles between Snohomish and Monroe and from 1½ to 3 miles in the delta downstream from Snohomish.

Figures 7-8, 7-9, and 7-10 show the probability of annual maximum flows for specified time periods for the Snohomish, Snoqualmie, and Skykomish Rivers.

**Flood Damages.** The estimated damages in Table 7-5 were determined from a detailed appraisal of the flood plain in 1961 and 1966. Average annual flood damages in the Snohomish, Snoqualmie and Skykomish flood plains are estimated to be $2,310,000.

In the agricultural setting of the Snohomish Basin, the greater part of the flood damage is to lands, crops and associated improvements. Table 7-6 tabulates these damages by the general damage categories described in the Puget Sound Area section of this appendix and the percentage of total damage from major floods.

**TABLE 7-6. Flood damage distribution**

| Category | Percent of Total Damage |
|---|---|
| Agriculture | 26 |
| Buildings & equipment | 35 |
| Transportation facilities | 15 |
| Diking, drainage and irrigation systems | 19 |
| Other | 5 |
| TOTAL losses and damage | 100 |

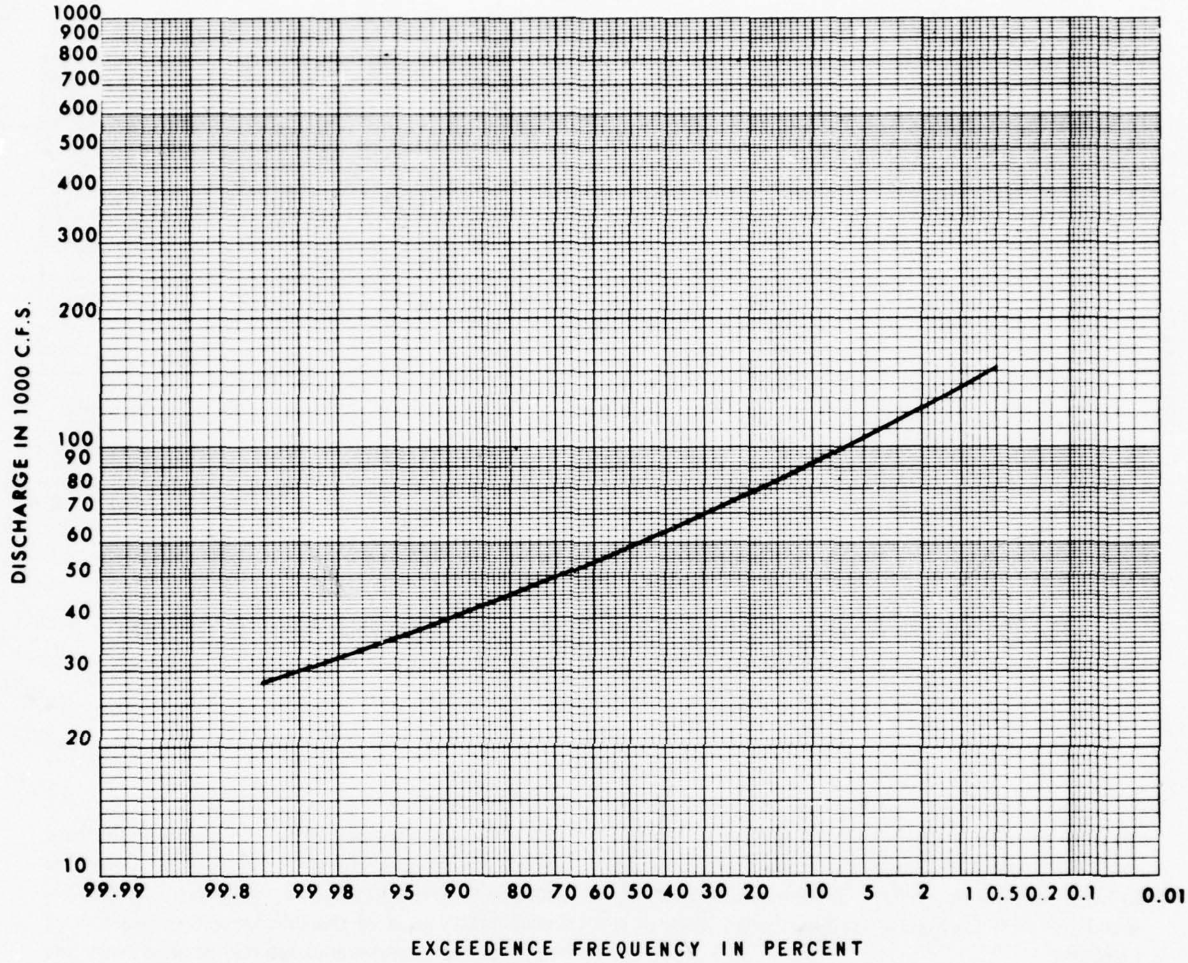



**FIGURE 7-8. Frequency curve of annual maximum peak flows, Snohomish River at Snohomish**

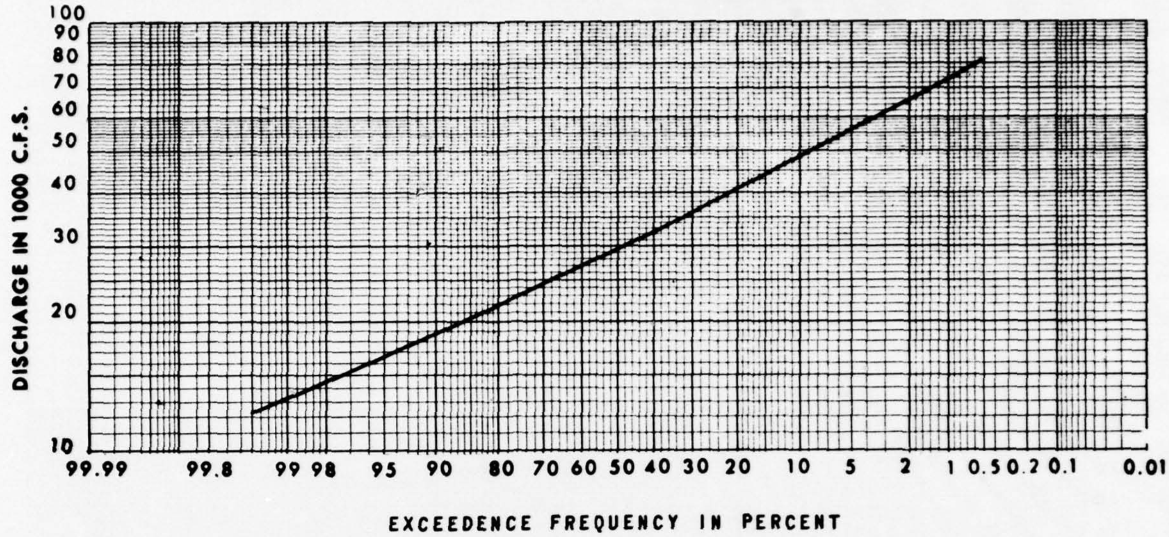



**FIGURE 7-9. Frequency curve of annual maximum peak flows, Snoqualmie River near Carnation**

The extent of flooding for progressively increasing riverflows and stages are shown in Figures 7-11, 7-12 and 7-13. Stages and flows are referenced to the gages Snohomish River at Snohomish, Snoqualmie River near Carnation and Skykomish River near Gold Bar.

## Existing Flood Control Measures

**Flood Forecasting and Warning.** The U.S. Weather Bureau provides the flood forecasting services described in the Puget Sound Area section of this appendix. Flood stage at the Snohomish gage is considered to be 25 feet above mean sea level. King and Snohomish Counties have flood control organizations that are activated when conditions warrant.

**Flood Protective Works.** Federal expenditures for flood protective works in the Snohomish Basin exceed $6,000,000. Known State, county and local expenditures are in excess of $5,800,000. These works consist of levees and bank protective works.

**Levees**

Snohomish River. Diking and drainage district levees provide some protection along the Snohomish River, but the degree of protection varies considerably. Most of the dikes would be overtopped by floods with a recurrence interval of once every one to five years. One area is protected against floods having an estimated recurrence interval of once in 40 years. Table 7-7 shows the level of protection provided by levees from the mouth of the Snohomish River to the confluence of the Skykomish and Snoqualmie Rivers.

The French Creek and Marshland Flood Control District requested assistance from the Soil Conservation Service to improve interior drainage and provide a higher level of flood protection. A project under the provisions of Public Law 566 was approved in 1959, and consists of raising existing levees and constructing drainage channels and pumping plants. The levees are designed to contain a flow of 65,000

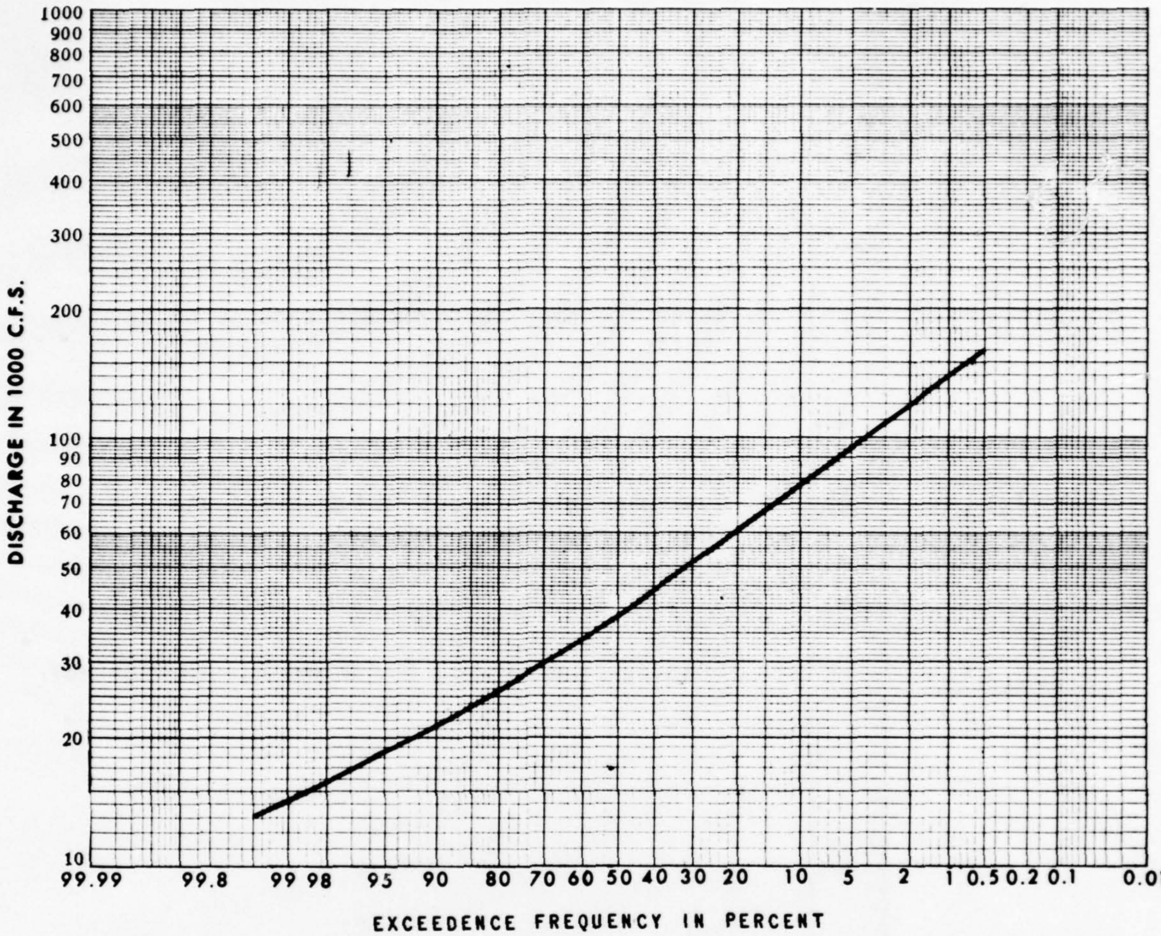



**FIGURE 7-10. Frequency curve of annual maximum peak flows, Skykomish River near Gold Bar**

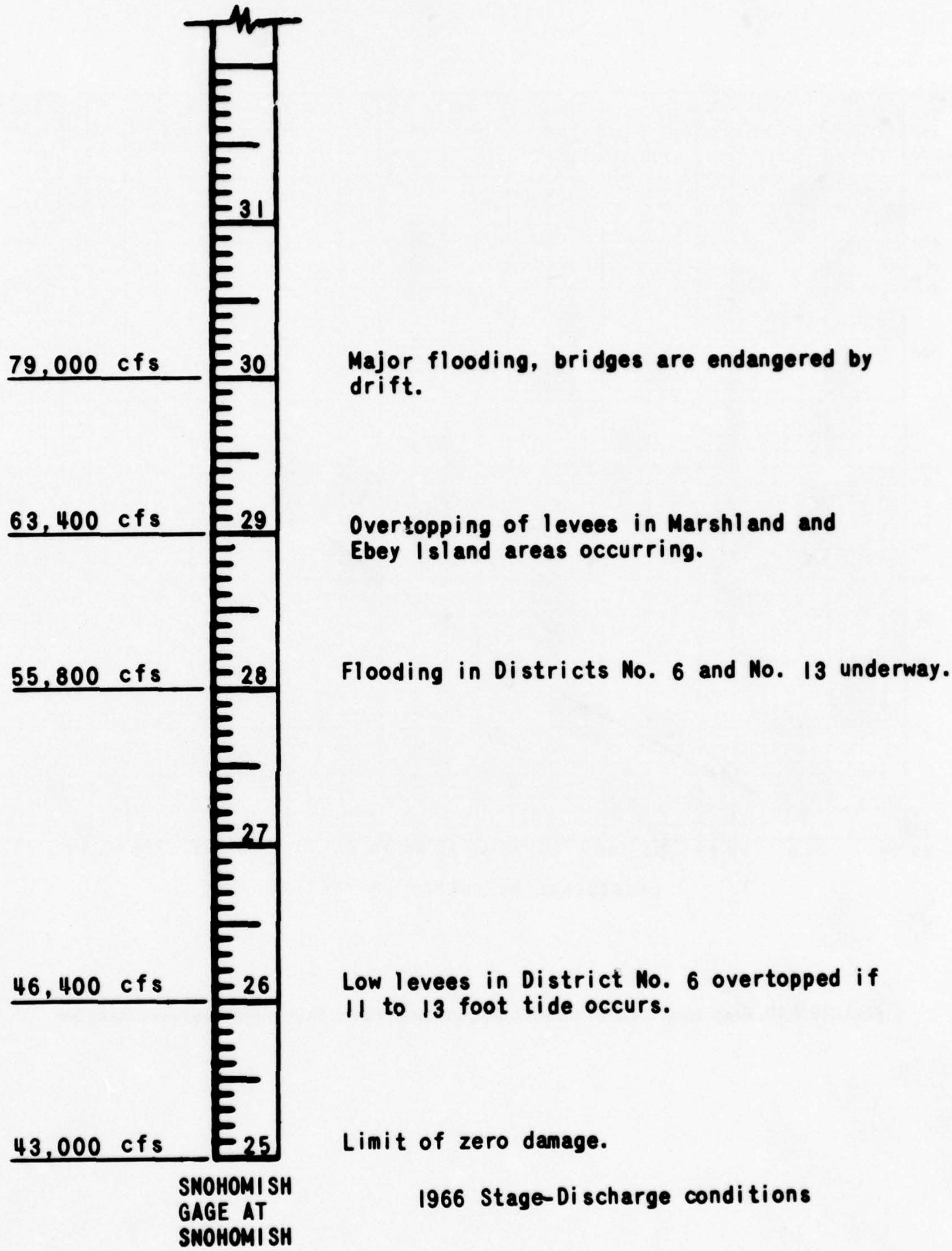



**FIGURE 7-11. Progressive stages of flooding, Snohomish River.**

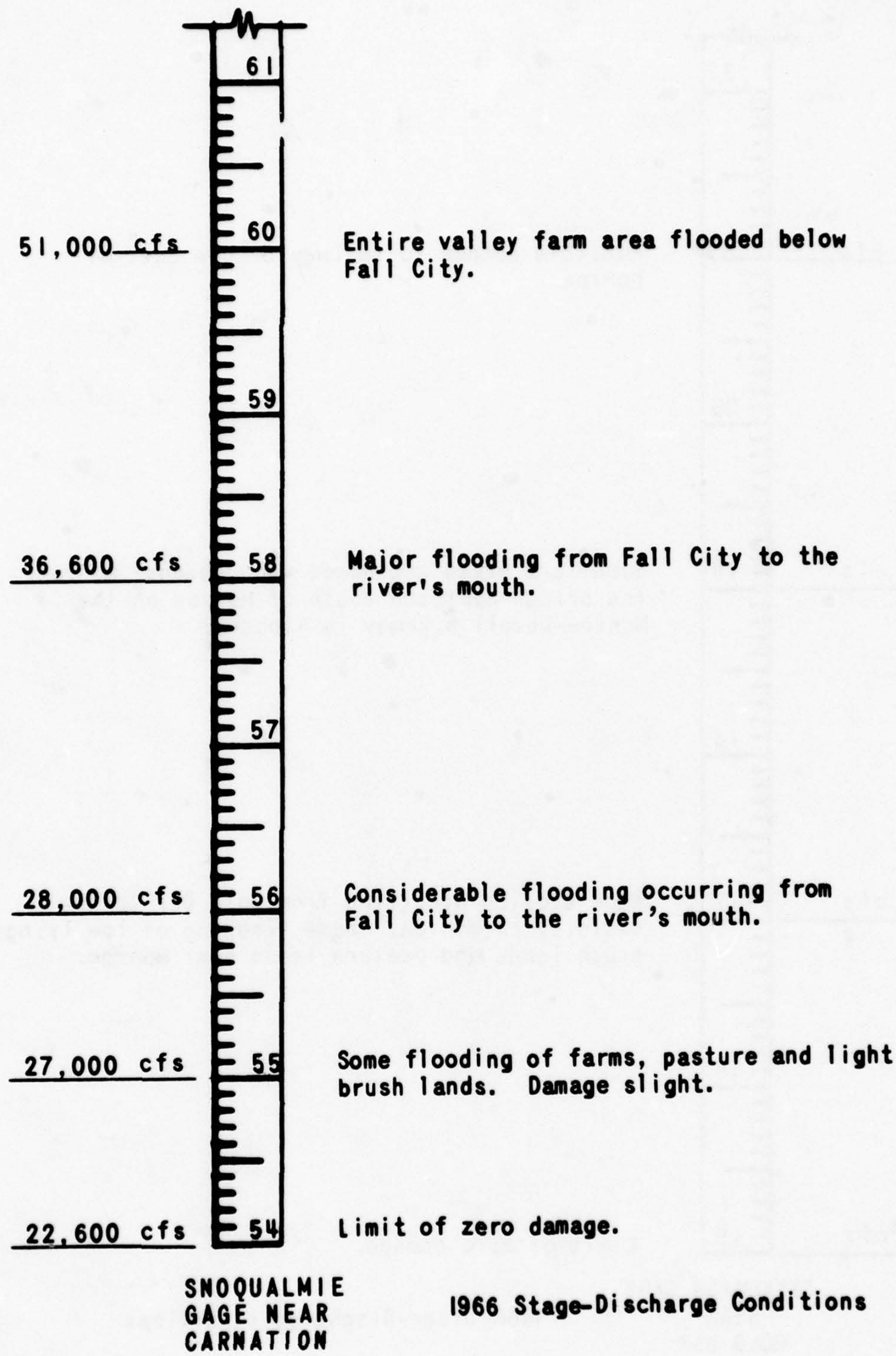



FIGURE 7-12. Progressive stages of flooding, Snoqualmie River.

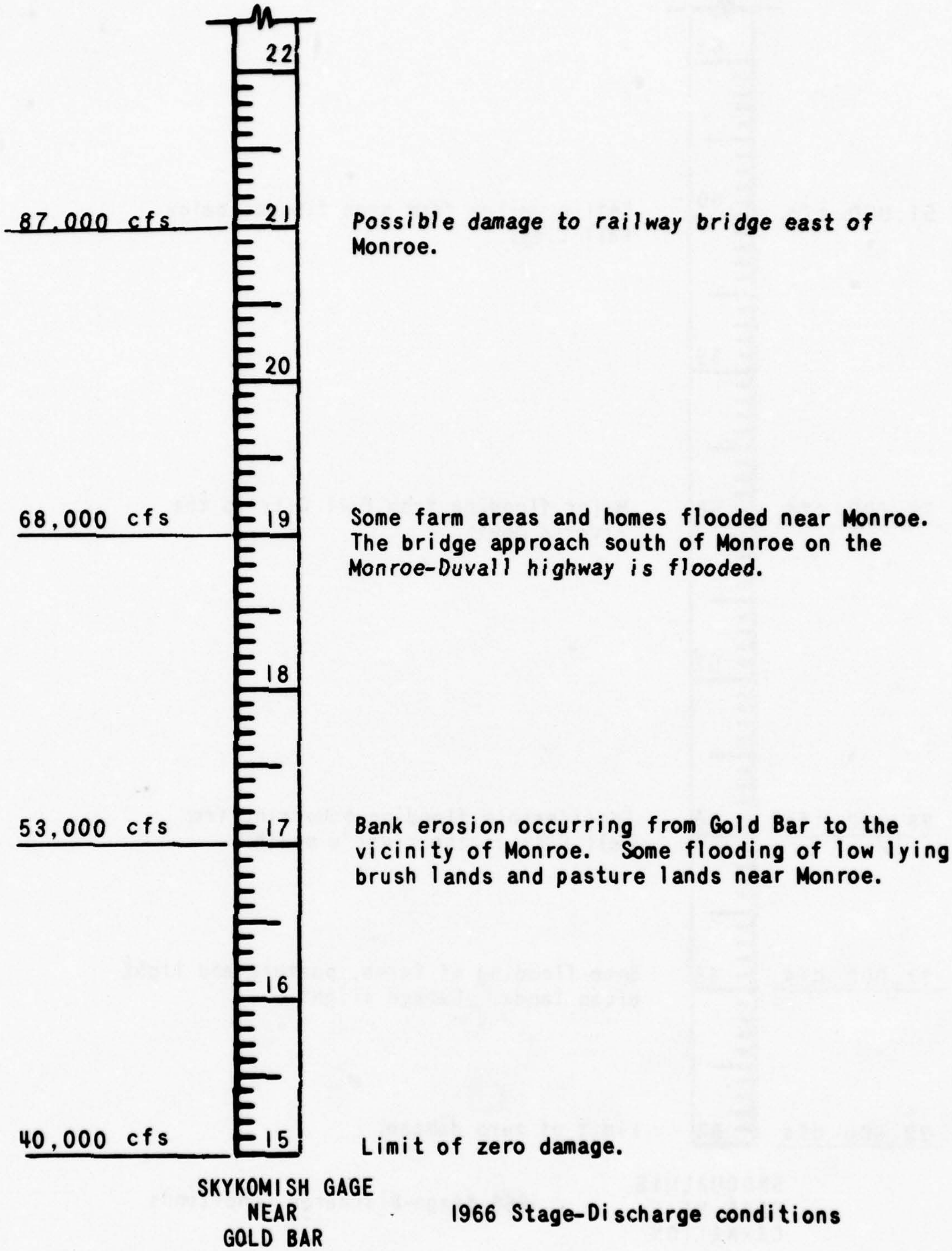



**FIGURE 7-13. Progressive stages of flooding, Skykomish River.**

cfs, measured at Snohomish, with 2 feet of freeboard. They will provide protection against winter flood-flows with a recurrence interval of once in 3 years and spring floodflows that can be expected to occur in excess of once in 25 years. The French Creek Project was completed in 1966 at a total cost of about $3,221,000. Work on the Marshland Project was about 85 percent complete in 1968 with the total cost estimated to be $4,265,000.

Other levees in Table 7-7 vary from 5 to about 15 feet in height and have top widths from 3 to about 24 feet. Some are built of sand, silt and gravel from adjacent lands or dredged from the river channel. Others are constructed of select materials and faced with rock riprap.

Snoqualmie River. Levees on the Tolt River, near its confluence with the Snoqualmie, provide moderate protection to urban development in the town of Carnation and to adjacent agricultural lands. A 600-acre agricultural area on the left bank of the Snoqualmie, one mile downstream from Fall City, is protected from minor spring floods by a levee about one mile long. Levees along the lower two miles of both banks of the Raging River and its

**TABLE 7-7. Protection provided by existing levees**

| Location | Area Protected (acres) | Miles of Levee | Protection: To Flow (cfs) | Protection: Recurrence Interval (years) |
|---|---|---|---|---|
| Diking Improvement Dist. No. 1 on right bank of Union Slough and Snohomish River (R.M. 0.0 to R.M. 10.5) | 3,554 | 13.1 | 59,000 | 2 |
| Diking Dist. No. 2—on right bank of Ebey Slough (R.M. 6 to R.M. 7.5) | 476 | 2.3 | 80,000 | 5 |
| Diking Dist No. 3—on right bank of Ebey Slough near Marysville | 405 | 1.0 | 160,000 | 200 |
| Diking Dist. No. 4—on right bank of Ebey Slough (R.M. 4 to R.M. 6). | 127 | 1.2 | 80,000 | 5 |
| Diking Dist. No. 5—Smith Island, bounded by Snohomish River on left and Union Slough on the right | 1,283 | 7.4 | 120,000 | 40 |
| Drainage Dist. No. 6—right bank Ebey Slough (R.M. 7.5 to R.M.10.5) | 517 | 2.4 | 50,000 | 1 |
| Drainage Dist. No. 13—right bank of Snohomish River (R.M. 10 to R.M. 13) | 533 | 2.9 | 59,000 | 2 |
| Marshland Flood Control Dist.—left bank of Snohomish River (R.M. 9 to R.M. 1) | 5,400 | 8.6 | 65,000 | 3 |
| French Slough Flood Control Dist.—right bank of Snohomish River (R.M. 16 to R.M. 19) | 6,200 | 4.4 | 65,000 | 3 |
| Small scattered private levees | 1,717 | 24.6 | Variable | Variable |
| TOTAL | 20,212 | 67.6 | | |

Note: R.M. = River Mile

confluence with the Snoqualmie, protect a portion of the town of Fall City and agricultural lands. Levees along the South Fork of the Snoqualmie River provide approximately 50-year flood protection to the town of North Bend.

Skykomish River. Levees at the towns of Skykomish, Index and Startup provide varying degrees of protection from high flows on the Skykomish River. The levee at Skykomish is approximately 2,000 feet long and protects only part of the town. The levee at Index has a varying cross section and provides only moderate protection. The levee at Startup extends about 7,000 feet along the right bank of the Skykomish River, ties into the Great Northern Railroad embankment on each end, and prevents the Skykomish from overflowing into the Wallace River. The project was constructed in 1965 by the Corps of Engineers at a total cost of $262,500, and provides 50-year protection.

**Bank Protection.** Bank erosion occurs at nearly all river stages, but is most severe during medium and high flows. Bank protection projects have been constructed at numerous locations along the Snohomish, Snoqualmie and Skykomish Rivers and their major tributaries by riparian owners, local governmental agencies, and the Federal Government. The Corps of Engineers has constructed bank protective works at 30 locations at a total Federal cost of $1,659,000.

**Channel Improvements.** Navigation improvements in Everett Harbor and the Snohomish River by the Corps of Engineers included dredging a channel 15 feet deep at mean lower low water from Port Gardner to the 14th Street Dock, a channel 8 feet deep from Everett Harbor to Steamboat Slough (a distance of approximately 6¼ miles), and settling basins at the upper end of Everett Harbor and at the upstream end of the navigation channel at Steamboat Slough. Federal costs for this project to 30 June 1966 totaled $1,348,500 for new work and $743,500 for maintenance, or a total of $2,092,100. The total Federal cost for previous channel improvements was $1,760,200 for new work, and $749,400 for maintenance, or a total of $2,509,700. The flood control benefits derived from this project are minor.

**Flood Control Storage.** Snohomish County Public Utility District No. 1 operates and maintains a dam and reservoir project on the Sultan River. This project provides 34,500 acre-feet of water supply storage for the city of Everett. Flood control storage is not provided. Diversion is accomplished by a spillway dam downstream from the storage reservoir, and the water is then carried through a tunnel to Lake Chaplain. The lake serves as an intermediate reservoir and has a storage capacity of 14,000 acre-feet. Water is delivered from Lake Chaplain to the city by pipeline. Domestic consumption and the extremely large requirements of the pulp and paper industry exceed the quantity of water available during the low summer flow period and necessitates storage. The public utility district plans future second-stage construction for additional water supply. Flood control storage could be provided in the second stage commensurate with economic justification.

In 1960, the city of Seattle constructed a water supply project with a capacity of 90 million gallons per day on the South Fork of the Tolt River. The total storage capacity of the reservoir is about 58,000 acre-feet. Flood control storage is not provided, and the project does not appreciably reduce flood discharges. The city is planning future construction of a diversion works on the North Fork to utilize natural flows for additional water supply.

**Flood Plain Management.** The Corps of Engineers published a flood plain study report on the Snohomish River Basin in June 1966. Snohomish County adopted flood plain regulations on April 15, 1968 and King County is in the process of preparing flood plain regulations.

## Flood Problems

**Main River.** The 59,000-acre flood plain of the Snohomish, Skykomish, and Snoqualmie Rivers is subject to frequent overbank flooding. Farmlands occupy most of the flood plain. However, industrial developments at Everett, Lowell and Snoqualmie Falls, and urban development in Carnation, Snoqualmie, North Bend, Sultan, Startup, Gold Bar, Monroe and Index encroach on the flood plain.

The Snoqualmie and Skykomish Rivers overflow their banks about every two years. Levees and bank stabilization projects provide varying degrees of protection for development in the flood plains. However, bedload deposits at the mouths of swift tributary streams restrict the channel capacities of these rivers, and resultant debris jams increase overbank flooding and streambank erosion. At the confluence of these rivers and in the upper 4 miles of the Snohomish River, sediments contributed largely by the Skykomish restrict the channel. These materials have formed a natural barrier that causes backwater and extensive flooding along the lower reaches of the

Snoqualmie and Skykomish Rivers. Any levee or channel improvement plan to reduce flooding in these valleys must take into consideration the effect such improvements would have on increased flooding in the Snohomish River flood plain.

Levees along the Snohomish River have varying dimensions, are constructed of various materials, and cannot withstand high, prolonged flood stages. The levees protect important agricultural lands against moderate spring floodflows but are not effective against large, spring floods. High winter flows overtop the levees at intervals of every one to five years. The heavy bedload carried by the Snohomish River causes shoaling in the downstream navigation channel.

**Tributary Streams.** Overbank flows cause severe bank erosion and damage approximately 1,100 acres of cultivated farmland adjacent to the lower four miles of the Sultan River; 1,000 acres of farmland bordering the Pilchuck River, in addition to the area within the Snohomish River flood plain; and 1,700 acres of farmland largely along the lower two miles of Woods Creek, a tributary of the Snohomish River.

Local interests have constructed levees and bank protective works on the right bank of the Pilchuck River about four miles above the rivermouth, and along both banks of the lower two miles of the stream. These works provide protection from flood flows of approximately 5,000 cfs, with a recurrence interval of about once in two years. The Corps of Engineers expended about $89,500 from 1946 through 1966 for emergency repairs, and $25,400 from 1946 to 1948 for snags and debris removal under the authority of P.L. 99 and Section 2 of the 1937 Flood control Act, respectively.

## PRESENT AND FUTURE NEEDS

### Evaluation of Present Situation

The 59,000-acre flood plain of the Snohomish, Snoqualmie, and Skykomish Rivers is subject to frequent flooding. Lands in the flood plain are utilized almost entirely for agriculture and contain farm buildings and residences, as well as portions of the towns of Carnation, Snoqualmie, North Bend, Monroe, Sultan, Gold Bar, and Index and several industrial enterprises located near Everett and Lowell. Flood damages begin when flows begin to exceed about 22,600, 40,000 and 43,000 cfs at Carnation, Gold Bar, and Snohomish, respectively. Average annual flood damages are estimated to be $2,310,000 and result from damages to crops and farmlands, residences and urban areas, roads, railroads, utilities and flood protective works.

The existing flood control system is not effective in controlling floods. The levees provide protection from normal spring floods which would otherwise severely damage crops. They do not prevent flooding by large spring or winter floods, particularly during periods of high tides. Overtopping of the levees along the Snohomish River may be expected at intervals of two to five years, depending on the height and conditions of the levees. Unprotected areas along the Snohomish, Snoqualmie, and Skykomish Rivers are flooded annually in lower areas and less frequently in higher areas. There are no flood control storage reservoirs to regulate flows, and the river discharges at Snohomish fluctuate widely from a maximum (1941 to present) of about 136,000 cfs in the flood season to less than 1,500 cfs in the late summer.

The steep gradient of the principal tributaries results in high discharge velocities which constantly erode the river banks. Debris and bedload are deposited in the lower river reaches where the stream gradient flattens. This diverts the stream channel causing further erosion or flooding. These conditions constrain the use of the flood plain to a level of agricultural use which is in consonance with periodic flooding.

In small watersheds, overbank flow from the main rivers as well as lack of adequate drainage facilities result in frequent flooding and considerable wetness of bottomlands. The Pilchuck River causes damage from streambank overflow and bank erosion.

### Economic Trends

The economy of the Snohomish River Basin is closely tied to the economic environment of neighboring counties and the Seattle-Everett metropolitan area. The pattern of economic growth for the Central Division comprising the counties of Snohomish, King, Pierce, and Kitsap is representative of the economic conditions in the basin. Projections of economic growth for the Central Division have been made for the years 1980, 2000 and 2020 in Appendix IV. Table 7-8 contains a forecast of population, employment and gross regional product for the Central Division and projects population for the Snohomish River Basin. Table 7-9 converts these forecasts into rates of growth and compares these rates to those projected for the United States.

**TABLE 7-8. Economic projections**

| Central Division | 1963 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Population (millions) | 1.6 | 2.4 | 3.9 | 6.2 |
| Employment (millions) | 0.6 | 0.9 | 1.4 | 2.2 |
| Gross Regional Product (millions 63 $) | 5,172 | 10,022 | 24,569 | 62,061 |
| Snohomish River Basin | | | | |
| Population (thousands) | 178.2 | 302.7 | 485.8 | 780.3 |

**TABLE 7-9. Average annual growth trends (percent)**

| | 1963 to 1980 | 1980 to 2000 | 2000 to 2020 | 1963 to 2020 |
|---|---|---|---|---|
| United States | | | | |
| Population | 1.3 | 1.3 | 1.3 | 1.3 |
| Employment | 1.6 | 1.4 | 1.3 | 1.5 |
| Gross National Product | 4.3 | 3.9 | 4.0 | 4.0 |
| Central Division | | | | |
| Population | 2.4 | 2.4 | 2.4 | 2.4 |
| Employment | 2.4 | 2.4 | 2.4 | 2.4 |
| Gross Regional Product | 3.9 | 4.6 | 4.7 | 4.4 |
| Snohomish River Basin | | | | |
| Population | 3.1 | 2.4 | 2.4 | 2.4 |

The Snohomish River Basin is adjacent to the Seattle-Everett metropolitan area and is directly in the path of current expansion and is expected to grow approximately at the rates of the Central Division. The population is estimated to rise from 178,000 in 1963, to 780,000 in 2020. Employment and gross regional product are expected to keep pace with population growth.

## Land Use Trends

The impact of the spiral of economic growth on the flood plain area is demonstrated in Table 7-10 which shows that the values of lands and buildings are increasing at a more rapid rate than farm production for the period 1944 to 1964. Increased urban and industrial use of flood plain lands can be expected in the future.

**TABLE 7-10. Growth patterns of land and developments**

| | Average Annual Growth Rate King County | Average Annual Growth Rate Snohomish County |
|---|---|---|
| Value of Land and Buildings | 8.5% | 7.3% |
| Value of all Farm Products Sold | 1.0% | 2.0% |

The trend toward higher use of flood-prone lands is exemplified by recent planning for the Snohomish River and its delta completed by Snohomish County in January 1968 with the aid of Tippets, Abbott, McCarthy and Stratton, Consultants. This plan provides for a self-maintaining channel in the delta area for flood control, reclamation of land by use of material dredged from the channel for a deep draft terminal for industry, flood control by levees and channel improvement, and retention of recreation and open space areas for land use control. Also in this area the Great Northern Railroad proposes the development of 425 acres of flood plain land for a rail classification yard to the Puget Sound Area.

## Flood Control Needs

**Prevention of Flood Damages.** The 59,000-acre flood plain of the Snohomish, Snoqualmie, and Skykomish River flood plain needs increased flood protection for existing developments. Average annual damages are estimated to be $2,310,000 and the damage that would result from a flood with an estimated frequency of 100 years is estimated to be $14,800,000.

Based on the methodology and considerations previously discussed for the Puget Sound Area, anticipated flood damages in the flood plains of the Snohomish River Basin are expected to increase by the percentages as shown in Table 7-11.

**TABLE 7-11. Percentage increase in productivity levels and developments for specified periods**

| Category of Damage | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Agriculture | 25 | 28 | 25 |
| Non-Agriculture | 60 | 110 | 110 |

Application of these percentages to the average annual damages based on 1966 prices and conditions provides an indication of future damages at 1966

prices if additional flood protection is not provided. Table 7-12 shows that the combination of all categories of damage are expected to increase from about \$2,310,000 in 1966 to \$13,100,000 by the year 2020.

**TABLE 7-12. Existing and future annual damages (in thousands of dollars)**

| Category | Under Development Levels of 1966 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Agriculture | 601 | 750 | 690 | 1,200 |
| Buildings & Equipment | 808 | 1,310 | 2,690 | 5,630 |
| Transportation Facilities | 346 | 560 | 1,150 | 2,410 |
| Other | 555 | 900 | 1,840 | 3,860 |
| TOTAL | 2,310 | 3,520 | 6,370 | 13,100 |

### Optimum Flood Plain Use.

**Agriculture.** Farmland is being converted and is expected to continue to be converted to other uses. The Snohomish Basin has 71,800 acres of cropland and this area is expected to decrease to about 60,000 acres by the year 2020. The majority of this decrease is expected to occur to croplands located in the flood plain. Production on the remaining lands must be increased as the overall demand of the Puget Sound Area continues to grow.

**Open Space.** The flood plains of the Snohomish, Snoqualmie, and Skykomish Rivers have been recommended for retention for open space by the Puget Sound Governmental Conference of the Puget Sound Regional Planning Council representing the counties of King, Pierce, Snohomish, and Kitsap, Washington. The open space designation expresses the local desire to hold the flood plain in its present agricultural use. More intensive agricultural use would also be compatible with the open space concept.

**Recreation.** Portions of the flood plain are forecast to be used for parks, golf courses and other general recreation uses such as swimming beaches, public boat launching ramps, and scenic drives. In order to permit construction of park facilities such as restrooms, and planting of trees and other greens, a level of flood protection of 10 to 15 years should be provided.

**Intensive Land Use.** The Snohomish Basin is presently experiencing a boom period of growth with the development of the Boeing complex at Paine Field, plus the tremendous growth of the basin as a suburban area for the Everett-Seattle metropolitan areas. Present trends indicate the past activity will continue for a number of years. Industrial development of approximately 9,000 acres in the delta of the Snohomish River is planned by Snohomish County by the year 2020. Additional intensive development is also likely to occur on the Snoqualmie River flood plain between Snoqualmie Falls and the town of North Bend.

### Summary of Flood Control Needs.

There is a need to reduce the present average annual flood damages of \$2,310,000 that occurs to croplands, buildings, transportation facilities and flood protective works. The trend of development within the basin is expected to result in the future growth of flood damages approximating 3¾ percent compounded annually if additional flood control is not provided. Future growth of average annual flood damages are expected to be \$3,520,000 in 1980, \$6,370,000 in 2000 and \$13,100,000 in 2020.

Flood control is required for more intensive agricultural utilization of flood plain lands. Industrial demands for a minimum of 2,000 acres in the Snohomish River delta area and 9,000 acres by the year 2020 would require at least a 100-year level of flood protection. Existing and future urban developments near the towns of Everett, Snohomish, Carnation, Snoqualmie, North Bend, Monroe, Sultan, Gold Bar, Index and Skykomish should be provided a 100-year level of flood protection. The entire flood plain should be managed to insure that land use is compatible with the degree of flood protection provided.

## MEANS TO SATISFY NEEDS

### Flood Control Objectives

The flood control objectives are to meet the needs set forth in the preceding section by providing flood control through utilization of both structural and non-structural measures. Objectives of structural measures are shown in Table 7-13. Non-structural measures would include a flood plain warning system and flood plain management consistent with the flood protection provided.

### Opportunities for Structural Measures

**Upstream Storage.** Approximately 700,000 acre-feet of flood control storage is required to provide a 100-year level of flood control in the basin.

TABLE 7-13. Objectives of structural measures

| Flood Plain Designation | Levels of Protection* 100 year | 25 year | 10-15 year |
|---|---|---|---|
| Snohomish River | | | |
| 7,300 acres in Snohomish River delta downstream of head of Ebey Slough including Everett. | X | | |
| 1,000 acres in vicinity of Snohomish | X | | |
| 12,000 acres of increased agricultural production from the head of Ebey Slough to the confluence of the Snoqualmie and Skykomish Rivers. | | X | |
| 1,000 acres along right bank of river downstream from Ebey Slough for recreation and open space. | | | X |
| 3,500 acres (includes area required for floodway) | | | X |
| Snoqualmie River | | | |
| 4,000 acres upstream from Snoqualmie Falls | X | | |
| 600 acres in the vicinity of Carnation. | X | | |
| 18,000 acres downstream from Snoqualmie Falls for improved agricultural lands | | X | |
| Skykomish River | | | |
| 2,500 acres in vicinities of Monroe, Sultan, and Gold Bar | X | | |
| 8,500 acres from Gold Bar to confluence for increased agricultural production | | X | |

* For floods that can be expected to occur on an average of once in the period designated.

There are only four storage sites suitable for development of major flood control storage. These are on the North and Middle Forks of Snoqualmie River, on the Sultan River, and on the North Fork of the Skykomish River. An aggregate of approximately 410,000 acre-feet of effective storage could be provided at these sites and would only control about 35 percent of the basin runoff. Small headwater storage sites on the Miller, Beckler, Pilchuck and South Fork Tolt River could provide an aggregate of approximately 140,000 acre-feet of effective storage and could control an additional 5 to 10 percent of the basin runoff.

**Levees and Channelization.** Flood control by major levee construction is effective for protection of urban areas, cities and towns extending into the flood plain, such as Everett, Snohomish, Monroe, Sultan, Gold Bar, Duvall, Carnation and North Bend. Levees are also effective in controlling floods in agricultural areas of Marshland and French Creek Flood Control districts along the Snohomish River, and agricultural areas along the Snoqualmie and Skykomish Valleys. Channelization improves the flood carrying capacity of the channel and could be effective in the lower Snohomish River and along the Snoqualmie and Skykomish Rivers.

## Solutions to Flood Control Needs

**General.** Features of the flood control plan are detailed in Table 7-14 and the main features of the plan are shown in Figure 7-14. Upstream storage is the nucleus of this plan. Levee and channel improvements together with flood plain management, supplement the upstream storage. The flood control plan would provide for optimum development and protection through the year 2020. Features of the plan are described as single-purpose flood control. Economic justification may depend on consideration of other water resource needs.

**Sequence of Development.**

**1980.** Storage for flood control could be constructed on the North and Middle Forks of Snoqualmie River and on the Sultan River. A floodway and tidal estuary channel constructed along the lower 5 miles of the Snohomish River delta by enlarging the Snohomish River channel could provide protection for industrial development in this area. Levees could be set back to provide an adequate floodway from the head of Ebey Slough to the confluence of Skykomish and Snoqualmie Rivers to provide for increased agricultural production. Flood plain zoning and regulation should be implemented commensurate with the level of flood protection provided.

**1980-2000.** Flood control storage could be constructed on the North Fork of the Skykomish River. The tidal estuary channel could be extended five miles upstream from the Interstate Highway 5 crossing to provide additional protected area for the projected industrial expansion. Modification of highway bridges would be required. Levees could be constructed to protect urban areas in the vicinities of Snohomish, Monroe, Gold Bar, Carnation, and Sultan.

**2000-2020.** The floodway in the lower Snohomish River could be extended to the head of Ebey Slough to provide for the projected industrial expansion. Flood control storage could be constructed on Miller, Beckler and Pilchuck Rivers. Levees could be raised along Snohomish River above Ebey Slough. Channel widening and deepening could be accomplished along the upper Snohomish and lower Skykomish and Snoqualmie Rivers in the vicinity of the confluence.

**Economic Analysis for 1980 Level of Flood Control.** Flood control storage must be combined with other multi-purpose uses for economic feasibility. Benefits for flood control storage realized by the year 1980 are given in Table 7-15. Also included are benefits and costs for levee and channel improvement works.

Annual costs include interest and amortization of the total investment (including interest during construction), average annual costs of operation and the equivalent average annual cost of major replacement costs. An interest rate of 4-5/8 percent was used to compute interest during construction and the annual costs of interest and amortization. An economic life of 100 years was used for storage projects

**Table 7-14. Flood Control Plan**

| Flood Control Feature | Effective Flood Control Storage Acre-Feet | River Mile | Height of Dam Ft. | Design Capacity cfs | Sequence of Development to 1980 | Sequence of Development to 2000 | Sequence of Development to 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|---|---|---|---|
| Flood Control Storage Projects | | | | | | | | |
| North Fork Snoqualmie River | 50,000 | 11.0 | 300 | | X | | | $ 29,200,000 |
| Middle Fork Snoqualmie River | 120,000 | 10.0 | 190 | | X | | | 40,700,000 |
| Sultan River | 100,000 | 14.0 | 265 | | X | | | 13,400,000 |
| North Fork Skykomish River | 140,000 | 6.2 | 340 | | | X | | 129,400,000 |
| Miller River | 45,000 | 0.6 | 230 | | | | X | 47,900,000 |
| Beckler River | 70,000 | 1.3 | 220 | | | | X | 43,900,000 |
| Pilchuck River | 15,000 | 22.0 | -- | | | | X | 15,700,000 |
| South Fork Tolt River | 15,000 | 6.6 | -- | | | | X | 2,000,000 |
| Channel and Levee Construction | | | | | | | | |
| Estuary Channel Snohomish River | | | | | | | | |
| 1. Mouth of Snohomish River to River Mile 3.0 | | | | 113,000 | X | | | 25,650,000 |
| 2. River Mile 3.0 to River Mile 6.3 | | | | 113,000 | | X | | 32,470,000 |
| 3. River Mile 6.3 to River Mile 10.0 | | | | 113,000 | | | X | 36,255,000 |
| Setback existing levee from River Mile 10.0 to River Mile 18.5 | | | | 90,000 | X | | | 6,300,000 |
| Levee Construction | | | | | | | | |
| Carnation—2 miles of levee | | | | 20,000 | | X | | 200,000 |
| Gold Bar—3 miles of levee | | | | 80,000 | | X | | 1,500,000 |
| Snohomish—1 mile of levee | | | | 15,000 | | X | | 200,000 |
| Sultan—3 miles of levee | | | | 80,000 | | X | | 1,500,000 |
| Monroe—3 miles of levee | | | | 85,000 | | X | | 1,500,000 |
| Flood Plain Management | | | | | X | X | X | 5,000[1] |
| TOTAL COST OF PLAN | | | | | | | | $425,780,000 |

[1] State of Washington, Snohomish and King County implementation costs only. Cost of the completed Flood Plain Information Study is not included.

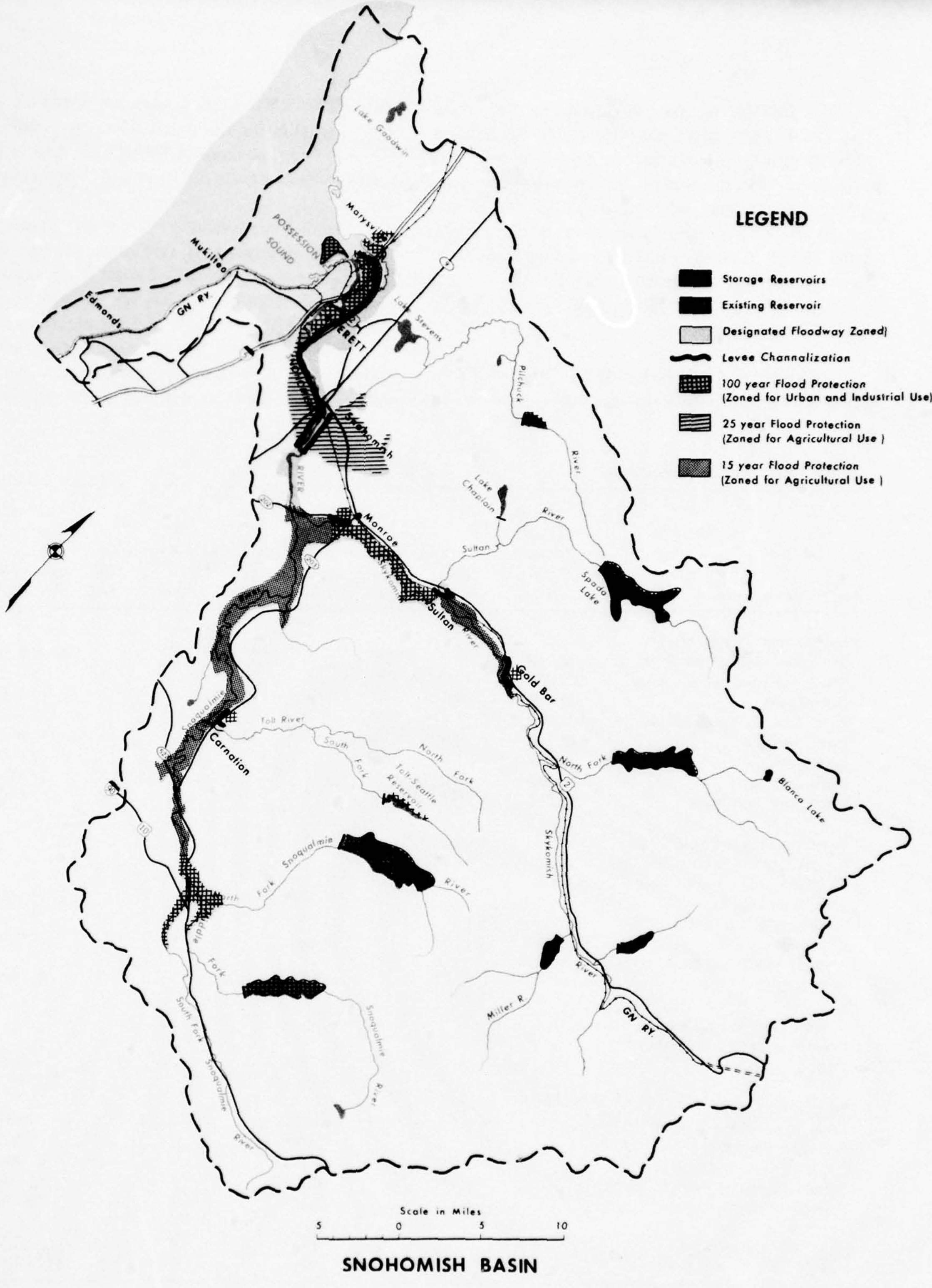



FIGURE 7-14. Proposed flood control plan and accomplishments

and an economic life of 50 years was used for levee construction.

Benefits are based on 1966 prices and include future growth. The 1980 projects are considered to be constructed at or near the same time period.

**Accomplishments.** Accomplishments of the flood control plan are shown in Table 7-16. One hundred year protection would be provided to 5,800 acres by 1980, 10,900 acres by 2000 and 15,400 acres by 2020. By 2020 an increased level of

**TABLE 7-15. Estimated costs and benefits for projects to be constructed prior to 1980**

| Project | Estimated[3] Total Constr. Costs | Estimated[3] Annual Cost | Estimated Annual Flood Damage Prevention Benefits | Estimated Annual Land Enhancement Benefits | Total Annual Benefits |
|---|---|---|---|---|---|
| North Fork Snoqualmie River Storage | $ 29,200,000 | $1,442,000 | $ 745,000 | $ 28,000 | $ 773,000 |
| Middle Fork Snoqualmie River Storage | 40,700,000 | 1,979,000 | 1,833,000 | 67,000 | 1,900,000 |
| Sultan River Storage | 13,400,000 | 657,000 | 707,000 | -- | 707,000 |
| Snohomish River Channel Improvement Mouth to River Mile 3 | 25,650,000 | 1,354,000 | 30,000 | 3,700,000 | 3,730,000 |
| Setback of Existing Levees—River Mile 10 to River Mile 18.5 | 6,300,000 | 378,000 | 400,000 | -- | 400,000 |
| Flood Plain Management | -- | 5,000[1] | 942,000[2] | -- | 942,000 |
| TOTAL | $115,250,000 | $6,310,000 | $4,657,000 | $3,795,000 | $8,452,000 |

1 Includes Federal, Snohomish and King County, and State of Washington administration and enforcement costs.
2 Based on reduction of future flood damages in the buildings and equipment category.
3 1968 price level.

**Table 7-16. Accomplishments of flood control plan**

| | To 1980 | To 2000 | To 2020 |
|---|---|---|---|
| Acreage Protected by Structural Measures | | | |
| 100-year | 5,800 | 10,900 | 15,400 |
| 25-year | 12,200 | 15,200 | 19,000 |
| 15-year | 20,000 | 20,000 | 16,000 |
| Less than 15 years | 21,000 | 16,000 | 8,600 |
| Change in Flood Plain Use | | | |
| Acres to industrial, commercial and residential | 5,800 | 10,900 | 15,400 |
| Acres to optimum agricultural | 12,200 | 15,200 | 19,000 |
| Acres to improved agricultural | 20,000 | 20,000 | 16,000 |
| Acres preserved for open space | 53,200 | 51,200 | 43,600 |
| Flood Plain Management (Acres) | 53,200 | 51,200 | 43,600 |
| Flood Damage Prevention (Dollars) | | | |
| Projected average annual flood damages without additional protection | $3,520,000 | $6,370,000 | $13,100,000 |
| Reduction in future average annual flood damages due to flood plain management | 256,000 | 941,000 | 2,411,000 |
| Projected residual average annual flood damage with flood plain management | 3,264,000 | 5,429,000 | 10,689,000 |
| Reduction in future average annual flood damages with implementation of structural measures | 1,984,000 | 4,239,000 | 9,268,000 |
| Residual average annual flood damages. | 1,280,000 | 1,190,000 | 1,421,000 |

agriculture would be possible on 35,000 acres of the flood plain and 43,600 acres of the 59,000-acre flood plain would remain in uses compatible with the preservation of open space.

**Alternatives Considered.** Levees and channel improvements were investigated as flood control measures as an alternative to upstream storage and were found to lack economic justification. Diversion of Snoqualmie River flows to the Sammamish River Basin was investigated but was not economically feasible.

The cost of raising roads and highways to reduce flood damages would exceed the benefits. Flood plain evacuation was precluded because of the magnitude of the existing improvements and facilities.

Floodproofing of existing buildings was evaluated as an alternative to major flood protective works for reduction of present and future flood damages. Urban developments in and near the towns of Everett, Snohomish, Monroe, Carnation, Snoqualmie, North Bend, Sultan, and Gold Bar as well as numerous residences and associated buildings located in rural areas of the flood plain would require floodproofing. Approximately 30 percent of the estimated $2,310,000 average annual flood damages or about $690,000 occurs to buildings. A high percentage of these buildings are of wood frame construction and floodproofing would require structural treatment that would be economically infeasible. This alternative would not meet the present or future needs for optimum development and utilization of the Snohomish Basin flood plain.

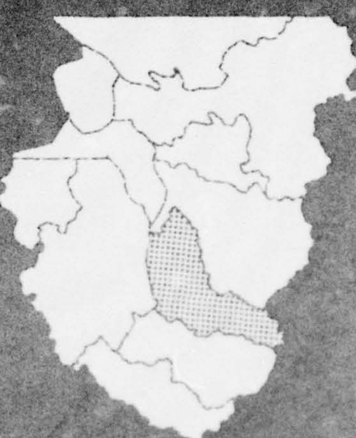
## Summary

The 59,000-acre flood plain of the Snohomish, Skykomish, and Snoqualmie Rivers is subject to frequent overbank flooding. Levees and bank stabilization projects provide some protection for development in the flood plains but floods overtop these protective works at intervals of every one to five years. Average annual flood damages are estimated to be $2,310,000 based on 1966 prices and conditions.

Anticipated growth indicates that future average annual flood damages may be expected to increase in proportion to the increase in economic activity in the flood plain are estimated to be $3,520,000 in 1980, $6,370,000 in 2000, and $13,100,000 in 2020 if additional protection is not provided.

Implementation of the flood control plan would significantly reduce flood plain damages and permit optimum utilization of the flood plain. Protection in excess of 100 years would be provided for industrial development in the Snohomish River delta and on the Snoqualmie River in the flood plain located between Snoqualmie Falls and the town of North Bend. Urban areas would be provided 100-year protection. Prime agricultural lands would be provided a 25-year level of flood protection and 43,600 acres of the 59,000 acre flood plain would remain in agricultural use and continue to provide open space for the Seattle and adjacent metropolitan area.

# Cedar-Green Basins



# CEDAR — GREEN BASINS

## DESCRIPTION OF BASINS

### GENERAL

The Cedar and Green River Basins, Figure 8-1, cover an area of 1,220 square miles, and are almost entirely in King County. These basins are bounded on the north by the Snohomish River Basin, on the east by the crest of the Cascade Mountains, on the south by the Puyallup River Basin, and on the west by Puget Sound. The eastern parts of the basin are extremely rugged, mountainous terrain with heavily forested foothills. Elevations vary from 1,000 feet in the foothills to 5,740 feet at the peak of Blowout Mountain. The principal streams are the Cedar and Sammamish Rivers, which discharge into Lake Washington, and the Green-Duwamish River which discharges into Elliott Bay, an arm of Puget Sound. Stream profiles are shown in Figures 8-2 and 8-3.

Soils of the mountainous areas in the eastern part of the watershed consist of shallow mantles of loams, stony and rocky loams overlying bedrock of basalt, slate, and shale. Soils of the western part of the basin were formed in cemented sandy glacial till, glacial clay till and outwash glacial sands and gravels. Their textures are loams, clay loams, sandy loams, gravelly sandy loams, sands and gravelly sands. The flood plains consist of sands and gravelly sands in the upper reaches and become progressively finer textured to fine sandy loams, silt loams, loams, clay loams and silty clay loams in the lower reaches. Peats and mucks occur in many small drainage basins.

The mild, wet climate is a product of maritime air that influences both precipitation and temperature. Approximately 75 percent of the precipitation falls during the period October through March. Mean annual precipitation varies from 32 to 35 inches near Seattle to more than 120 inches near the crest of the Cascade Mountains. Precipitation falls in the form of snow in the higher elevations. The mean annual snowfall varies from 5.9 inches near the town of Kent to 457.6 inches at Stampede Pass. The maximum annual snowfall recorded at Stampede Pass is 578.9 inches. The mean annual temperature varies from 39.5°F. at Stampede Pass to 51.1°F. at the Seattle-Tacoma International Airport. At these stations, mean temperatures in January vary from 23.5°F. to 38.3°F. and in July from 56.2°F. to 64.9°F., respectively.

### ECONOMY—PAST AND PRESENT

The eastern parts of the basins are sparsely populated and contain controlled-use watersheds utilized for municipal water supply by the cities of Tacoma and Seattle. The western parts of the basins are heavily populated and the flood plains are extensively developed for agricultural, commercial, industrial and residential uses. Table 8-1 gives historic population trends for the basin and its environment.

Table 8-2 contains historical data on employment trends. Employment in these basins is greatly influenced by the aircraft and allied equipment industry. Other important industries include the processing of primary metals and the manufacture of fabricated metals. The deep water port at Seattle, low cost electric power and abundant fresh water have stimulated rapid industrial expansion. Farmlands in the Cedar, Sammamish and Green River Valleys are being rapidly converted to residential, commercial and industrial use to accommodate the increasing population and industrial growth.

### ECONOMIC TRENDS

The economy of the entire Cedar-Green River Basins is closely tied to the economic environment of Snohomish, King, and Pierce Counties and the Tacoma-Seattle-Everett metropolitan area. The pattern of economic growth for the Central Division comprising the counties of Snohomish, King, Pierce, and Kitsap is representative of the economic conditions in the basin. Projections of economic growth for the Central Division have been made for the years 1980, 2000 and 2020 in Appendix IV. Table 8-3 contains a forecast of population, employment and

**TABLE 8-1. Population—past and present**

| Area | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940–1967 |
|---|---|---|---|---|---|
| United States (thousands) | 132,164 | 151,326 | 179,323 | 200,100 | 52 |
| Puget Sound (thousands) | 1,007 | 1,418 | 1,768 | 2,100 | 105 |
| Central Division (thousands) | | | | | |
| 4 counties | 820 | 1,196 | 1,513 | 1,751.2 | 114 |
| Cedar-Green Basins (thousands) | 500 | 723 | 924 | 1,072.4 | 114 |
| Cities & Towns in the Basin (thousands) | | | | | |
| Seattle | 368.3 | 467.6 | 557.1 | 580.0 | 58 |
| Renton | 4.5 | 16.0 | 18.5 | 23.1 | 414 |
| Bellevue | --- | --- | 12.8 | 22.0 | --- |
| Auburn | 4.2 | 6.5 | 11.9 | 17.1 | 306 |
| Kent | 2.6 | 3.3 | 9.0 | 14.0 | 442 |
| Redmond | 0.5 | 0.6 | 1.4 | 6.1 | 1,053 |
| Enumclaw | 2.6 | 2.8 | 3.3 | 3.9 | 49 |
| Bothell | 0.8 | 1.0 | 2.2 | 4.1 | 417 |
| Issaquah | 0.8 | 1.0 | 1.9 | 3.5 | 334 |

Figures are from U.S. Census Report; Seattle Area Industrial Council, 1967, and Economics Appendix IV.

**TABLE 8-2. Employment—past and present**

| Industry | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940–1967 |
|---|---|---|---|---|---|
| Agriculture | 6,615 | 5,769 | 4,653 | 2,500 | -26 |
| Forest, Fishery, Mining | 3,155 | 2,927 | 1,368 | 2,800 | -11 |
| Contract Construction | 11,970 | 20,178 | 20,671 | 27,400 | 23 |
| Manufacturing | (38,526) | (57,403) | (100,399) | (169,000) | 339 |
| Food and kindred products | 5,157 | 7,339 | 8,837 | 10,000 | --- |
| Lumber, wood and furniture | 7,586 | 7,330 | 5,954 | 5,600 | --- |
| Paper and allied products | 507 | 700 | 1,116 | 1,300 | --- |
| Chemical and allied products | 915 | 1,316 | 1,474 | 1,000 | --- |
| Fabricated metal | 659 | 3,345 | 5,193 | 5,500 | --- |
| Machinery (Elect & Non-Elec) | 1,898 | 3,380 | 6,049 | 8,100 | --- |
| Transportation equipment | 8,947 | 20,087 | 54,838 | 106,300 | --- |
| Primary metals | 8,253 | 11,068 | 14,455 | 28,400 | --- |
| Non-commodity industry | 131,974 | 195,550 | 235,643 | 329,000 | 149 |
| Total employment | 192,240 | 281,827 | 362,734 | 530,700 | 176 |

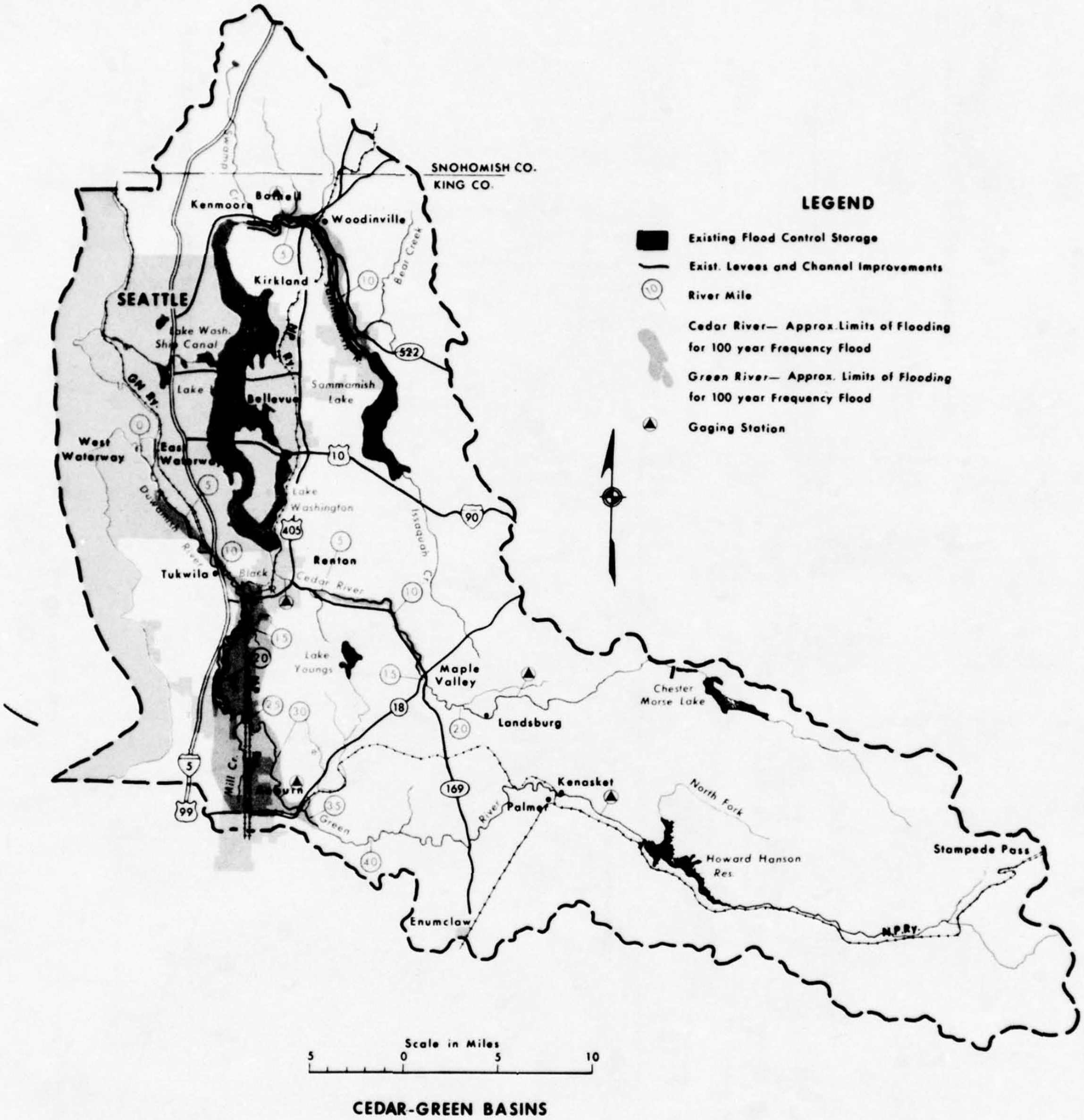
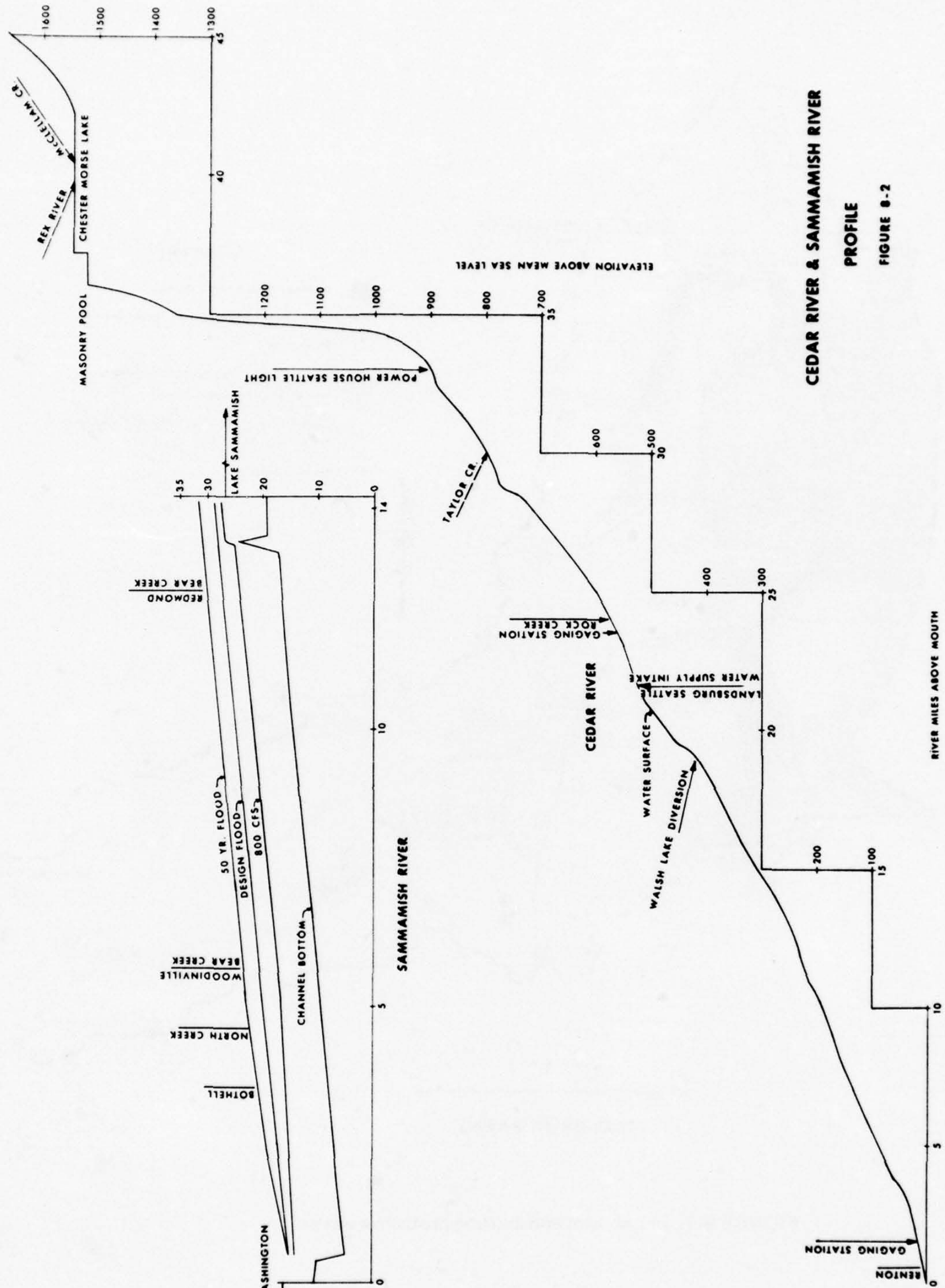


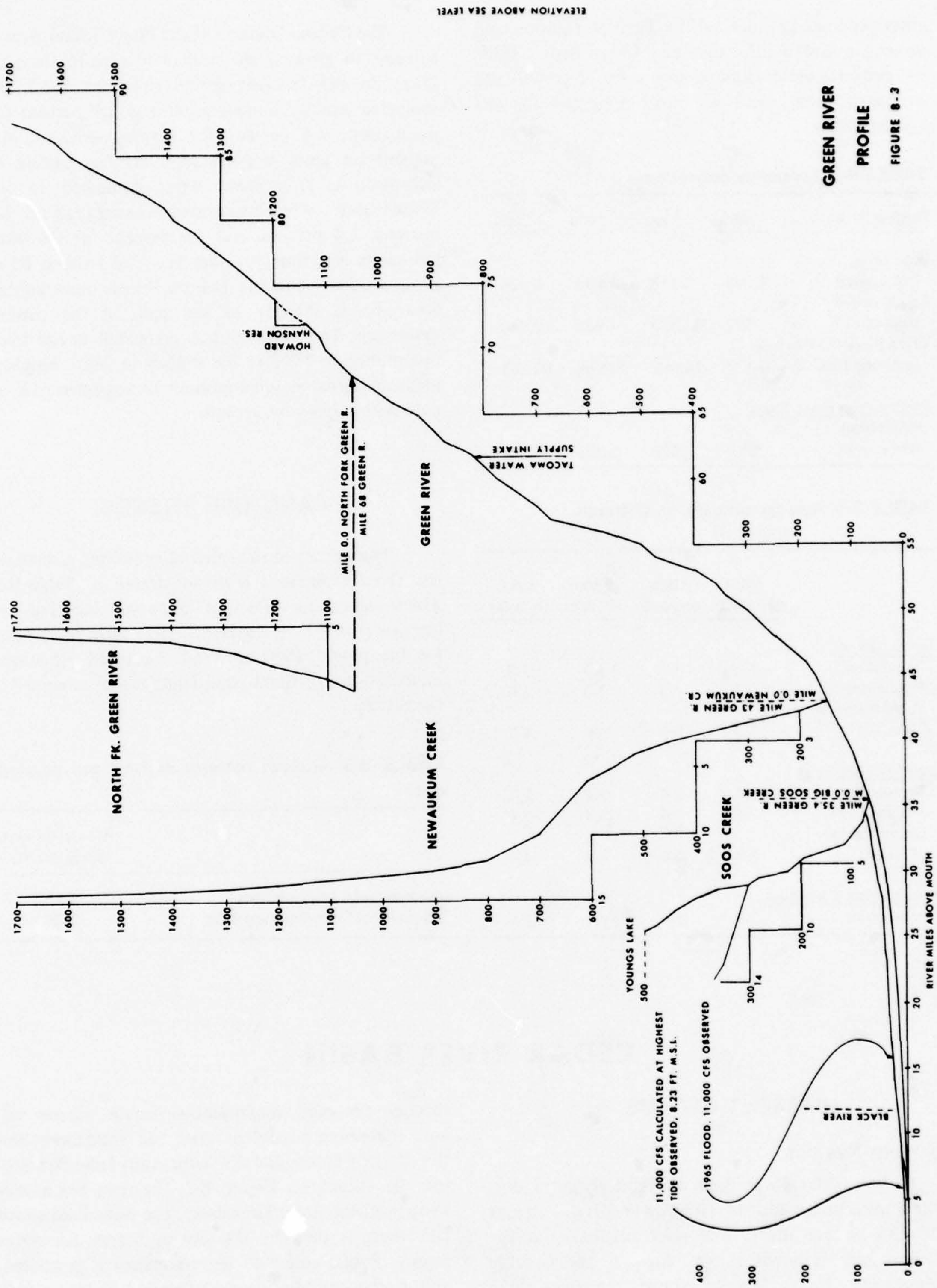

FIGURE 8-1. Flood plain and existing protective works




CEDAR RIVER & SAMMAMISH RIVER

PROFILE

FIGURE 8-2




GREEN RIVER PROFILE

FIGURE 8-3

gross regional product of the Central Division and projects population for the Cedar-Green Basins. Table 8-4 converts these forecasts into rates of growth and compares these rates to those projected for the United States.

**TABLE 8-3. Economic projections**

| Central Division | 1963 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Population (thousands) | 1,603 | 2,419 | 3,882 | 6,236 |
| Employment (thousands) | 579 | 873 | 1,400 | 2,248 |
| Gross Regional Product (millions 1963 $) | 5,172 | 10,022 | 24,569 | 62,061 |
| Cedar-Green River Basin | | | | |
| Population (thousands) | 976.9 | 1,479 | 2,376 | 3,816 |

**TABLE 8-4. Average annual growth trends. (percent)**

| | 1963 to 1980 | 1980 to 2000 | 2000 to 2020 | 1963 to 2020 |
|---|---|---|---|---|
| United States | | | | |
| Population | 1.3 | 1.3 | 1.3 | 1.3 |
| Employment | 1.6 | 1.4 | 1.3 | 1.5 |
| Gross National Product | 4.3 | 3.9 | 4.0 | 4.0 |
| Central Division | | | | |
| Population | 2.4 | 2.4 | 2.4 | 2.4 |
| Employment | 2.4 | 2.4 | 2.4 | 2.4 |
| Gross Regional Product | 3.9 | 4.6 | 4.7 | 4.4 |
| Cedar-Green River Basin | | | | |
| Population | 2.4 | 2.4 | 2.4 | 2.4 |

The Central Division of the Puget Sound Area is forecast to grow at an accelerated rate to the year 2000. In the 57-year period following 1963, the projected average annual growth is 2.4 percent for population, 2.4 percent for employment, and 4.4 percent for gross regional product. The pattern of expansion is emphasized when compared to the United States which is expected to realize rates of 1.3 percent, 1.4 percent, and 4.0 percent for the same indicators and time periods. The Cedar-Green River Basin is adjacent to the Tacoma-Seattle metropolitan area and is directly in the path of the current expansion. The population is estimated to rise from one million in 1963 to 3.8 million in 2020. Employment and gross regional product are expected to keep pace with population growth.

## LAND USE TRENDS

The impact of the spiral of economic growth on the flood plain area is demonstrated in Table 8-5, which shows the values of lands and buildings are increasing at a more rapid rate than farm production for the period 1944 to 1964. Increased urban and industrial use of flood plain lands can be expected in the future.

**TABLE 8-5. Growth patterns of land and developments**

| | Annual Growth King County |
|---|---|
| Value of Land and Buildings | 8.5% |
| Value of All Farm Products Sold | 1.0% |

# CEDAR RIVER BASIN

## PRESENT STATUS

### Stream System

The Cedar River Basin is about 40 miles long, has a maximum width of 10 miles and drains an area of 188 square miles. The river originates in the Snoqualmie National Forest, high in the Cascade Mountains. In its 50-mile course, the river flows through timbered, mountainous terrain, narrow valleys containing scattered farms and residences, and the city of Renton, and discharges into Lake Washington. As shown on Figure 8-2, the river has a very steep gradient above Landsburg. The watershed above Landsburg is used by the city of Seattle for water supply. Public access to the watershed is restricted, and logging operations are regulated to maintain good

PHOTO 8-1. Cedar River near Cedar Grove (2 miles downstream from Maple Valley). View looking downstream, showing debris from November 1959 flood.

hydrologic cover. The city's water supply reservoir is a raised, natural lake now called Chester Morse Lake. The principal tributary below the lake is Taylor Creek, also within the watershed. The basin contains approximately 195,000 acres of commercial forest land. About 50 percent of the forest land is privately owned. Much of the privately owned timber in lowland areas was harvested during the past century. Most of the remaining saw timber is in stands along the upper reaches of the Cedar River.

## Flood Plain

The flood plain of the Cedar River is very narrow throughout its length, but contains about 800 acres of fertile land. Most of this land is downstream from the town of Maple Valley. The area subject to flooding is shown on Figure 8-1. From its source to a point near Landsburg, the river occupies a well-defined channel.

From Maple Valley to Renton, a distance of 15 miles, the river occupies a braided channel containing numerous sand and gravel bars. The riverbanks are generally composed of sands and gravels which erode easily during high water stages and high velocities. Shifting of the channel is common during high water, and scouring undermines trees and vegetation. The resulting debris often forms jams which deflect the current against the banks, causing further erosion and changes in the channel configuration. Typical debris and bank erosion are shown in Photo 8-1.

Landsburg, Maple Valley and Renton are the only communities in the flood plain. Farmlands are gradually being converted to residential use to accommodate the increasing population of Greater Seattle. Beginning about 2 miles upstream from the town of Maple Valley, rustic homes border some reaches downstream to Renton and further residential developments are under construction.

Coal mining, once a very important industry, has dwindled to minor proportions. None of the presently-operated mines is adversely affected by floodwater. Employment is high in the aircraft industry, as well as in the clay products and steel fabrication industries. The Chicago, Milwaukee, St. Paul and Pacific Railroad, and county and secondary State highways pass through this narrow valley.

The major diversion of water from the Cedar River is for the city of Seattle water supply. Chester Morse Lake, formed by the city's water supply dam, provides 52,000 acre-feet of active storage. A pipeline with a capacity of 300 cfs diverts water to Lake Young, an equilizing reservoir in the water supply system.

## History of Flooding

**Flood Characteristics.** Topographic and climatic conditions of the Cedar River Basin produce two highwater periods each year. The highest flows normally result from extreme rainfall and accompany snowmelt during December and January. The flow recedes slightly as spring approaches, then increases again from snowmelt during April, May and June. Flows during the dry summer months are relatively high because of regulated storage in Chester Morse Lake and sizeable groundwater contributions from natural storage in the lowlands above Landsburg. Figures 8-4 and 8-5 show the monthly runoff pattern and the daily discharge hydrograph for Cedar River near Landsburg. Taylor Creek, the principal tributary, had a peak discharge of 2,730 cfs at a gaging station near Selleck on 29 January 1965. The Cedar River crested near Landsburg on 30 January with a flow of 4,640 cfs.

**Floods.** Streamflow on the Cedar River has been recorded almost continuously since 1895 at a gage near Landsburg. The gage measures runoff from 122 square miles, including 17.2 square miles drained by Taylor Creek. Measured at Landsburg, zero damage flow from the mouth to river mile 4.5 is estimated to be 4,200 cfs. From river mile 4.4 to river mile 17.5, 2.5 miles above Maple Valley, the zero damage flow is estimated to be 1,570 cfs. Figures 8-6 and 8-7 show that flows of 4,200 cfs and 1,570 cfs have a recurrence interval of once in seven years and once annually, respectively. Table 8-6 lists some major discharges for the Cedar River during the period of record. Photos 8-2, 8-3 and 8-4 are scenes of the February 1965 flood.

**Flood Damages.** The first detailed flood damage appraisal for the Cedar River flood plain was made by the Corps of Engineers in 1941. In July 1966, the appraisal was updated to 1966 prices and conditions. Based on these appraisals, the average annual flood damages for the Cedar River flood plain are estimated to be $117,000. Estimated flood damages for some recent large floods are tabulated in Table 8-7. In the urban setting of the lower flood plain, most of the damage is to buildings and equipment. Agricultural lands, and railway and highway improvements suffer minor damage. Details on types of flood damages are discussed in the Puget Sound Area Section of this appendix.

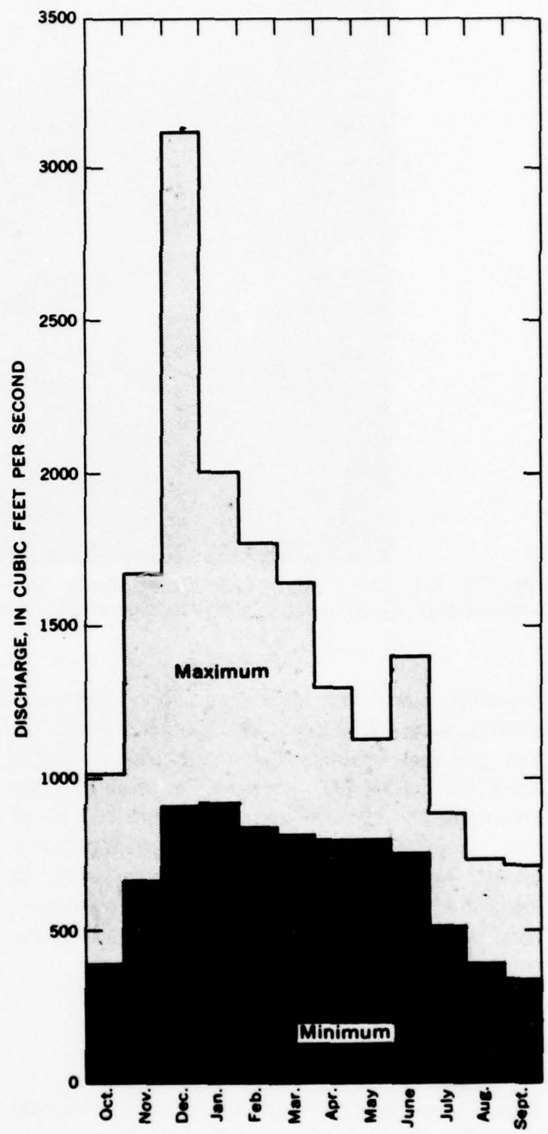



FIGURE 8-4. Maximum, mean and minimum monthly discharges, Cedar River near Landsburg, 1931-60.

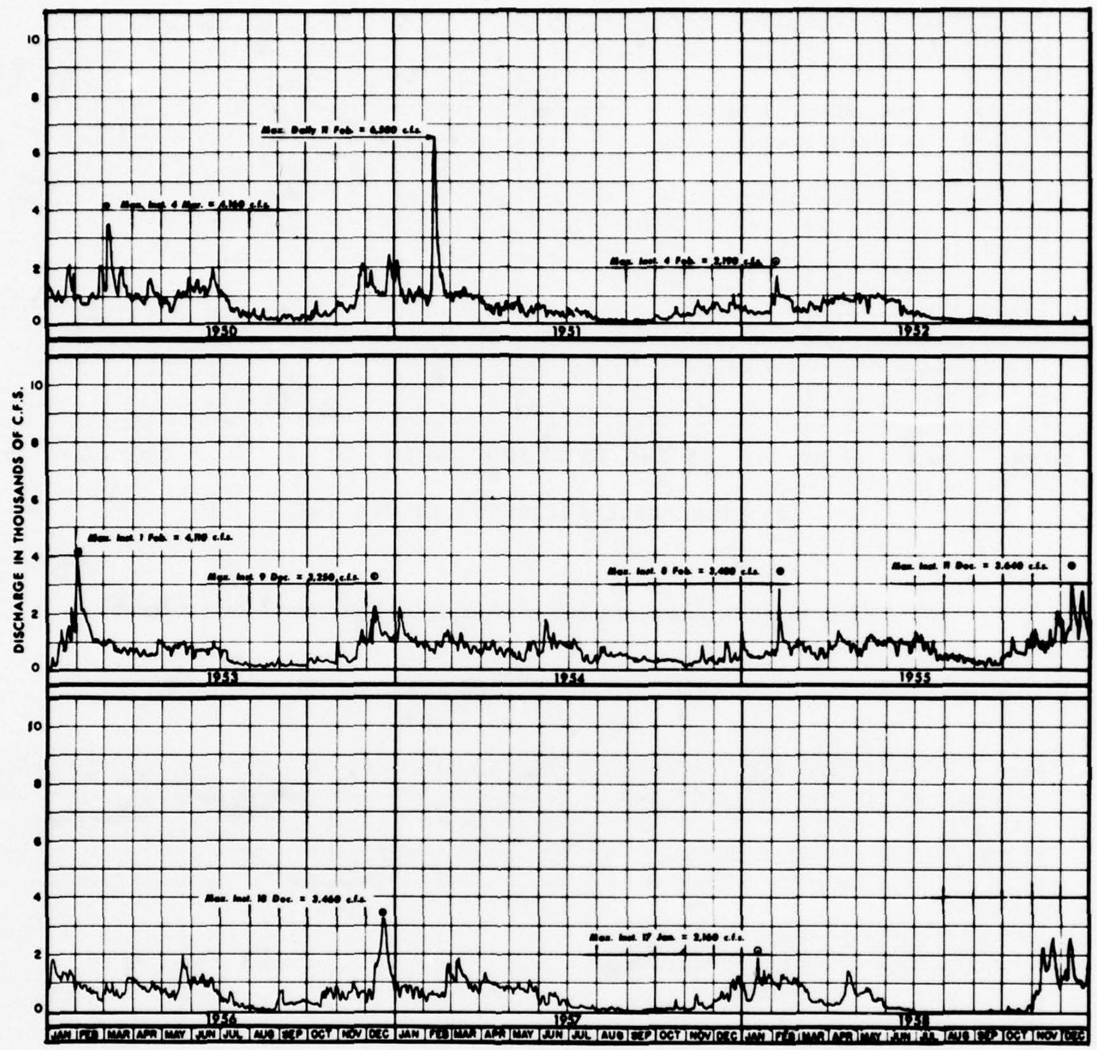



**FIGURE 8-5. Daily discharge hydrograph, Cedar River at Renton.**

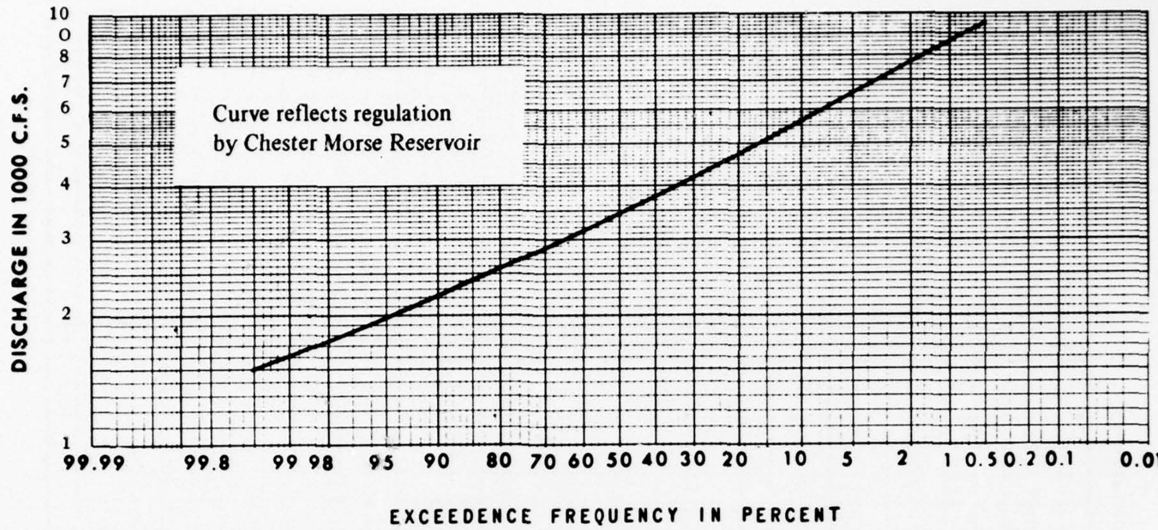



**FIGURE 8-6. Frequency curve of annual maximum peak flows, Cedar River at Renton**

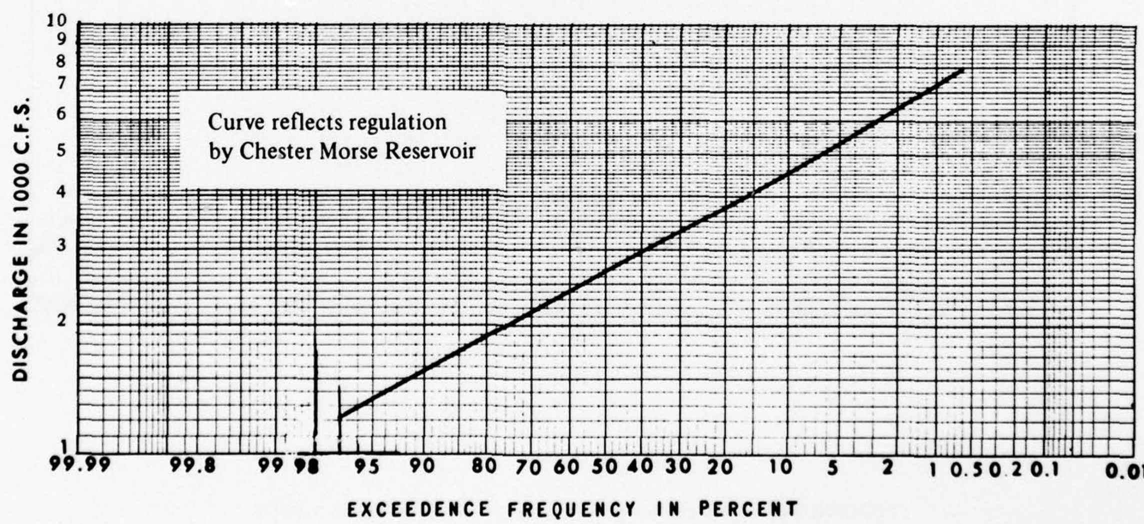



**FIGURE 8-7. Frequency curve of annual maximum peak flows, Cedar River near Landsburg**

TABLE 8-6. Peak discharges greater than zero damage (4,200 cfs at Landsburg)

| Date | Discharge (cfs) | Date | Discharge (cfs) |
|---|---|---|---|
| Jan 9 or 10, 1896 | 3,420 | Jan 8, 1933 | 4,300 |
| Nov 14 or 15, 1896 | 5,380 | Dec 22, 1933 | 7,520 |
| Nov 19, 1897 | 5,030 | Jan 25, 1935 | 4.160 |
| Dec 24, 1901 | 3,790 | May 17, 1936 | 1,900 |
| Jan 5, 1903 | 10,200 | Jun 20, 1937 | 1,800 |
| Jan 15, 1904 | 2,020 | Nov 29, 1937 | 2,360 |
| May 24, 1905 | 2,080 | Feb 15, 1939 | 1,500 |
| Jan 25, 1906 | 2,020 | Mar 7, 1940 | 1,880 |
| Nov 15, 1906 | 12,400 | Nov 28, 1940 | 1,050 |
| Mar 16, 1908 | 5,100 | Dec 19, 1941 | 1,830 |
| Jan 14, 1909 | 2,480 | Nov 23, 1942 | 2,140 |
| Nov 23, 1909 | 8,370 | May 24, 1944 | 1,380 |
| Nov 21, 1910 | 4,520 | Feb 7, 1945 | 1,970 |
| Nov 19, 1911 | 14,200[1] | Dec 28, 1945 | 2,040 |
| Jan 3, 1913 | 3,790 | Dec 14, 1946 | 4,190 |
| Apr 4, 1915 | 1,330 | Nov 11, 13, 1947 | 1,940 |
| Mar 10, 1916 | 2,630 | Feb 17, 1949 | 1,750 |
| Jun 17, 1917 | 2,240 | Mar 5, 1950 | 3,050 |
| Dec 29, 1917 | 7,500 | Feb 11, 1951 | 6,200 |
| Jan 22, 1919 | 3,160 | Feb 4, 1952 | 1,740 |
| Jan 28, 1920 | 1,860 | Feb 1, 1953 | 3,370 |
| Feb 11, 12, 1921 | 1,920 | Dec 9, 1953 | 2,770 |
| Dec 12, 1921 | 5,960 | Feb 8, 1955 | 2,720 |
| Jan 10, 1923 | 4,160 | Dec 11, 1955 | 3,280 |
| Feb 12, 1924 | 3,100 | Dec 18, 1956 | 3,240 |
| Feb 8, 1925 | 2,740 | Jan 17, 1958 | 1,570 |
| Jan 5, 1926 | 1,720 | Jan 24, 1959 | 3,460 |
| Jan 2, 1927 | 1,820 | Nov 24, 1959 | 4,840 |
| Jan 13, 1928 | 4,860 | Feb 21, 1961 | 2,350 |
| Mar 31, 1929 | 1,180 | Dec 24, 1961 | 1,960 |
| Jan 4, 1930 | 1,350 | Jan 3, 1963 | 1,930 |
| Mar 31, 1931 | 1,200 | Jun 18, 1964 | 2,340 |
| Feb 26, 1932 | 4,860 | Jan 30, 1965 | 4,640 |

[1] 14,200 cfs actually observed. However, much of the flow was caused by flashboard failure at the city of Seattle dam. The estimated flow was 8,740 cfs without the flashboard failure.

## Existing Flood Control Measures

**Flood Forecasting and Warning.** The U.S. Weather Bureau provides the flood forecasting services described in the Puget Sound Area Section of this appendix.

King County has established a flood fighting plan based on maintaining a channel capacity of 4,200 cfs at Landsburg. The plan consists of patrolling and making emergency repairs to contain this discharge. When the flow exceeds 4,200 cfs, efforts are concentrated on saving lives and personal property. The Sheriff's office, the Office of Civil Defense, fire districts, and the Red Cross are contacted for assistance.

TABLE 8-7. Major floods and estimated damages.

| Date | Peak Discharge at Landsburg (cfs) | Average Recurrence Interval (years) | Current Estimated Damages |
|---|---|---|---|
| 22 Dec 1933 | 7,520 | 120 | $1,188,000 |
| 11 Feb 1951 | 6,200 | 50 | 597,000 |
| 30 Jan 1965 | 4,640 | 11 | 216,000 |

**Flood Protective Works.** The Cedar River is an uncontrolled stream; however, channel improvements, bank protective works and a water supply dam provide some incidental flood control benefits.

PHOTO 8-2. February 1965 flood. River mile 6.5, looking downstream. The river broke through a sand and gravel processing area.

*PHOTO 8-3. February 1965 flood at river mile 5.8, looking downstream. Note encroachment on channel width.*

PHOTO 8-4. February 1965 flood at river mile 14.8, looking downstream.

**Channel Improvements.** The lower one-mile reach of the Cedar River channel was stabilized in 1912. The channel has a capacity of about 9,500 cfs, and provides protection from floodflows with a recurrence interval of once in about 100 years. Only minor overbank flows and negligible flood damage have been experienced in this reach. Expenditures for maintenance dredging totaled about $524,000 from 1912 to 1957.

**Bank Protection.** King County has expended more than $570,000 in the last 25 years on flood and erosion control works. The work included riprap bank protective works, bulkheads, and cleaning and snag removal in the reaches below Landsburg to establish and maintain a channel capacity of 4,200 cfs.

**Upstream Storage.** The city of Seattle diverts water at Landsburg for municipal water supply. A pipeline with a capacity of 300 cfs carries water to Lake Young, which serves as an equalizing reservoir. The city also has built two dams to provide storage for the generation of hydroelectric power. A rockfill, timber-crib dam constructed in 1903 at the outlet of Chester Morse Lake raised the water level to elevation 1,548 feet, providing 16,000 acre-feet. During construction, an opening 40 feet wide with a sill elevation of 1,554. 61 feet was left in the dam as a temporary spillway. Partial filling of the pool behind the masonry dam resulted in seepage through the morainal deposit forming the right valley wall. Seepage appeared as springs downstream from the dam and in the valley of the South Fork of the Snoqualmie River at elevations some 800 feet lower than Chester Morse Lake. In December 1918, when the city began to raise the pool, a slide and washout occurred on the northern face of the morainal wall above the South Fork of the Snoqualmie River. The pool was at an elevation of 1,556 feet at the time this catastrophe occurred. Sand and gravel estimated at over one million cubic yards were washed into the Snoqualmie Valley, destroying the tracks of the Chicago, Milwaukee, St. Paul and Pacific Railroad, a small village and a sawmill.

Because of the seepage problem, the masonry dam cannot be used for the purpose originally intended. The maximum pool elevation is still determined by the sill elevation of the uncompleted opening. When lake stages rise above elevation 1554.6, the masonry dam serves as an uncontrolled spillway.

**Flood Plain Management.** The Cedar Basin has no zoning or regulatory ordinances to control developments in the flood plain. However, the Corps of Engineers has established the Flood Plain Management Service described in the Puget Sound Area Section of this appendix. King County plans to adopt zoning ordinances designating the floodway and a fringe area to prevent encroachment on the flood plain.

### Flood Problems

The Cedar River flood plain is subject to frequent flooding. Minor flooding and bank erosion occurs when the riverflow exceeds 1,570 cfs, a flow with a recurrence interval of once every year. Floods with the magnitude of the December 1933 flood would inundate the entire valley. This was the largest flood in recent years having a discharge of 7,520 cfs, and a recurrence interval of once in 100 years.

The December 1933 flood resulted in only minor overbank flows and negligible flood damage adjacent to the improved channel through Renton. The deposition of bedload in this reach could cause serious problems; however, the removal of sand and gravel by an aggregate processing company just upstream from Renton has relieved the flood threat in recent years.

Overland flooding and ponding in the densely populated Lake Washington watershed are not directly related to riverflows. These problems, caused by heavy precipitation and inadequate drainage facilities, result in damage to recreational, residential and urban development, and are discussed in Appendix XIV, Watershed Management.

## PRESENT AND FUTURE NEEDS

### Evaluation of Present Situation

The 800-acre flood plain of the Cedar River is subject to frequent flooding. The flood plain contains portions of the communities of Landsburg, Maple Valley and Renton, and agricultural land is being rapidly converted to residential use. Housing developments upstream from Renton are subject to damage from major flows.

The Cedar River is an uncontrolled stream, except for incidental flood control storage by dams above Landsburg, bank stabilization works, and the improved channel from just upstream of Renton to the mouth. An uncontrolled spillway at one of these dams reduces peak discharges, but flood control benefits are minor. Bank stabilization works in several reaches from Renton upstream to Maple Valley contain the river within its banks during normal flows, but present works were not intended to prevent overtopping by major flows. Consequently, flows exceeding 4,200 cfs at Landsburg can be expected to overtop some portions of the riverbank between Renton and river mile 4.5. From river mile 4.5 to about 17.5, overtopping begins when the flow is 1,570 cfs at Landsburg. The improved channel through Renton appears to have the capacity to carry 9,500 cfs, a flood with estimated recurrence interval of once in about 200 years. Average annual flood damages are estimated to be $117,000. Most of the damage is to buildings and equipment.

Inadequate drainage channels result in flooding and ponding in the Lake Washington watershed, and the problem is increasing with rapid development of the area.

### Flood Control Needs

**Prevention of Flood Damages.** The 800-acre flood plain of the Cedar River needs increased flood protection for existing developments. Average annual damages are estimated to be $117,000 and the damages that would result from a flood with an estimated frequency of 100 years are estimated to be $1,188,000. Losses of this magnitude must be reduced by increasing the existing level of flood protection. Flood plain lands should be zoned to insure that future development of these lands is orderly and consistent with the protection provided.

Based on the methodology and considerations previously discussed for the Puget Sound Area, flood damages in the flood plains of the Cedar River Basin are expected to increase by the percentages as shown in Table 8-8.

**TABLE 8-8. Percentage increase in productivity levels and developments for specified periods**

| Category of Damage | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Agriculture | 26 | 24 | 26 |
| Non-Agriculture | 75 | 120 | 120 |

Application of these percentages to the average annual damages based on 1966 prices and conditions provides an indication of future damages at 1966

prices if additional flood protection is not provided. Table 8-9 shows that the combination of all categories of damage are expected to increase from about $117,000 in 1966 to $975,000 by the year 2020.

**TABLE 8-9. Existing and future annual damages (in thousands of dollars)**

| Category | Under Development Levels of 1966 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Agriculture | 4 | 5 | 6 | 7 |
| Buildings and Equipment | 96 | 167 | 369 | 815 |
| Transportation Equipment | 6 | 10 | 23 | 51 |
| Other | 11 | 21 | 46 | 102 |
| Total | 117 | 203 | 444 | 975 |

### Optimum Flood Plain Use.

**Agriculture.** Farmland is being rapidly converted to residential and commercial use as a result of the expansion of the Seattle-Renton metropolitan area. Flood plain lands expected to remain in agricultural production should be provided a 25-year level of protection.

**Recreation.** Portions of the flood plain will be designated as recreation areas. The Cedar River is an excellent trout and steelhead fishing stream and this recreation resource could be further enhanced by improved access. Additional campgrounds, picnic areas and golf courses will be required and a level of flood protection of 10 to 15 years is needed.

**Intensive Land Use.** Residential and industrial developments are rapidly encroaching on the flood plain area below the town of Maple Valley. Flood damages can be expected to increase. Optimum development of the flood plain for residential or industrial use would require at least a 100-year level of flood protection.

## Summary of Flood Control Needs

There is a need to reduce the present flood damages of $117,000 that occurs annually to agricultural lands, buildings and equipment, and transportation systems. The trend of development within the basin is expected to result in the future growth of flood damages approximating 4 percent compounded annually, without flood control, and will result in future growth of annual damages to $202,000 in 1980, $444,000 in 2000, and $975,000 in 2020.

Additional flood control is desirable to protect the urban and residential developments that are rapidly encroaching on the flood plain area in the river reach from the rivermouth to the town of Maple Valley. A 100-year level of protection should be provided to these lands so that the full economic potential of this flood plain could be realized. Flood plain lands should be managed to permit developments that are commensurate with the flood protection provided.

# MEANS TO SATISFY NEEDS

## Flood Control Objectives

The flood control objectives are to meet the needs set forth in the preceding section by providing flood control through utilization of both structural and non-structural measures. Objectives of the structural measures are to provide a 100-year level of flood protection. Non-structural measures would include a flood plain warning system and flood plain management consistent with the flood protection provided.

## Opportunities for Structural Measures

**Upstream Storage.** Flood protection would be significantly increased if flood control storage were provided. In order to provide 100-year protection for the flood plain, storage would have to be provided on both the Cedar River and its major tributaries. Raising of the city of Seattle's reservoir at Chester Morse Lake on the Cedar River could provide some flood control storage. Additional storage would be required downstream on the Cedar River, or on tributaries to the Cedar River, to accomplish a 100-year level of protection for the Cedar River flood plain.

**Levees and Channelization.** The 800-acre flood plain of the Cedar River is scattered along the lower 20 mile river reach and has a maximum width of about one-half mile. Levee and channelization projects could protect portions of this flood plain.

## Solutions to Flood Control Needs

**General.** Features of the flood control plan are detailed in Table 8-10 and shown on Figure 8-8. Upstream storage and flood plain management are the nucleus of the plan. The flood control plan would provide for optimum development and protection through 2020. Features of the plan are described as single-purpose flood control. Economic justification

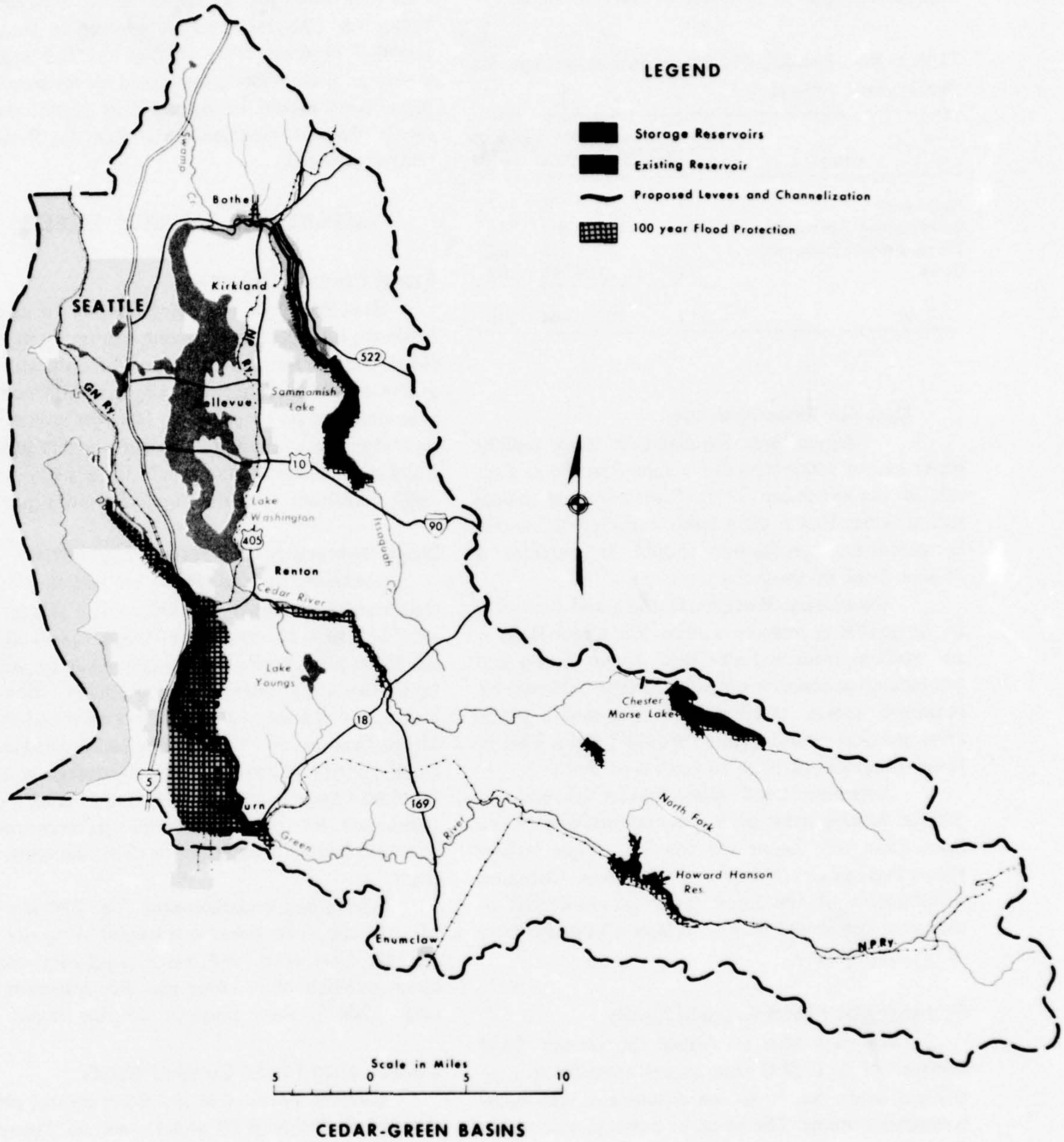



FIGURE 8-8. Proposed flood control plan and accomplishments

**TABLE 8-10. Flood control plan**

| Flood Control Feature | Effective Flood Control Storage acre-feet | River Mile | Height of Dam Feet | Sequence of Development to 1980 | to 2000 | to 2020 | Estimated Development Costs for Project Based on January 1968 Costs |
|---|---|---|---|---|---|---|---|
| Flood Control Storage Projects | | | | | | | |
| Increasing Storage at Chester Morse Lake | 50,000 | 83 | 80 | X | | | $ 5,610,000 |
| Taylor Creek Dams | 10,000 | 5 | 100 | | | X | $10,200,000 |
| Flood Plain Management | | | | X | X | X | $ 54,000[1] |
| Total Cost of Plan | | | | | | | $15,864,000 |

[1]Includes estimated cost of a Flood Plain Information Study and flood plain zoning and regulation implementation costs.

may depend on consideration of other water resource needs.

**Sequence of Development.**

**To 1980.** Storage for flood control could be constructed on the Cedar River in conjunction with raising of the existing reservoir owned by the city of Seattle. Flood plain zoning and regulation should be adopted commensurate with the level of flood protection provided.

**1980-2020.** In this period the developments in the flood plain as a result of pressure for intensive use of the flood plain lands may require additional protection. Flood control storage on Taylor Creek would provide 100-year protection. Flood plain regulation should be continued.

**Economic Analysis of the 1980 Level of Flood Control.** Flood control storage must be combined with other multi-purpose uses for economic feasibility. Benefits and cost data for flood control storage planned by the year 1980 are given in Table 8-11. Annual costs include interest and amortization of the total investment (including interest during construction), average annual costs of operation and equivalent average annual cost of major replacement costs. An interest rate of 4-5/8 percent was used to compute interest during construction and interest on amortization. An economic life of 100 years was used for storage projects.

Flood control benefits are based on the reduction of present and future flood damages and benefits resulting from land enhancement. Benefits are based on January 1968 prices.

**Accomplishments.** By 1980 flood control storage in the city of Seattle's reservoir on Cedar River could provide a high degree of protection against spring floods to the 800-acre flood plain. By 2020 flood control storage on Taylor Creek could provide 100-year protection for the entire 800-acre flood plain in the basin. Flood plain zoning and regulation would insure that future development of the flood plain is consistent with the level of flood protection provided. Accomplishments are shown in Table 8-12.

**TABLE 8-11. Estimated costs and benefits for projects to be constructed prior to 1980.**

| Project | Estimated[3] Total Construction Costs | Estimated[3] Annual Costs | Estimated Annual Flood Damage Prevention Benefits | Estimated Annual Land Enhancement Benefits | Total Annual Benefits |
|---|---|---|---|---|---|
| Increasing Storage at Chester Morse Lake | $5,610,000 | $312,000 | $268,000 | $30,000 | $298,000 |
| Flood Plain Management | --- | 4,000[1] | 47,000[2] | - | 47,000 |
| Total Cost | $5,610,000 | $316,000 | $315,000 | $30,000 | $345,000 |

[1]Includes Federal, King County, and State of Washington administration and enforcement costs.

[2]Based on reduction of future flood damages in the buildings and equipment category.

[3] 1968 price level.

**TABLE 8-12. Accomplishments of flood control plan**

| Acreage Protected by Flood Control Plan | 1980 | 2000 | 2020 |
|---|---|---|---|
| 100-year protection | --- | --- | 800 |
| 25-year protection | 500 | 500 | --- |
| Less than 25 year | 300 | 300 | --- |
| Flood Plain Management (acres) | 800 | 800 | --- |
| Flood Damage Prevention (dollars) | | | |
| Projected average annual flood damages without additional protection | $202,000 | $444,000 | $975,000 |
| Reduction in future average annual flood damages due to flood plain management | 35,000 | 137,000 | 360,000 |
| Projected residual average annual flood damages with flood plain management | 167,000 | 307,000 | 615,000 |
| Reduction in future average annual flood damages with implementation of structural measures | 129,000 | 236,000 | 578,000 |
| Projected residual average annual flood damages | 38,000 | 71,000 | 37,000 |

**Alternatives Considered.** Levees and channel improvements were investigated as flood control measures as an alternative to upstream storage and were found to be economically unfeasible due to the magnitude of right-of-way costs required and the small flood plain area that would be protected. Flood plain evacuation was found to be economically unfeasible because of the magnitude of the existing improvements and facilities that would require relocation.

Floodproofing of existing buildings was evaluated as an alternative to major flood protective works for reduction of present and future flood damages. Approximately 60 percent of the estimated $117,000 average annual flood damages, or about $70,000, occurs to buildings. A high percentage of these buildings are wood frame construction and floodproofing would require structural treatment that is economically infeasible. This alternative would not meet the present or future needs for optimum development and utilization of the Cedar Basin flood plain.

## Summary

Flooding of portions of the 800-acre Cedar River flood plain occurs frequently. Damage occurs to a suburban area, agricultural lands, and summer homes located upstream from Renton. The improved channel through Renton and the Boeing Company industrual lands is estimated to have sufficient capacity to accommodate a flood with an estimated average recurrence interval of 200 years.

Anticipated growth indicates that future flood damages may be expected to increase in proportion to the increase in economic activity in the flood plain if additional protection is not provided. Average annual flood damages under future conditions are estimated to be $202,000 in 1980, $444,000 in 2000, and $975,000 in 2020.

Implementation of the flood plan would significantly reduce flood plain damages and permit increased utilization. Protection in excess of 100 years would be provided to the flood plain.

# SAMMAMISH RIVER BASIN

## PRESENT STATUS

### Stream System

The Sammamish River Basin is about 30 miles long, ha. a maximum width of 8 miles, and comprises an area of 240 square miles. The elevations of low mountains in the upper basin do not exceed 2,500 feet. Issaquah Creek and numerous small creeks rise in forested foothills and flow into Lake Sammamish The principal towns are Issaquah, Redmond, Woodinville, Bothell and Kenmore.

Lake Sammamish, the largest lake in the basin, is near the center of the valley. The lake is about 11 miles east of Seattle and is a highly developed

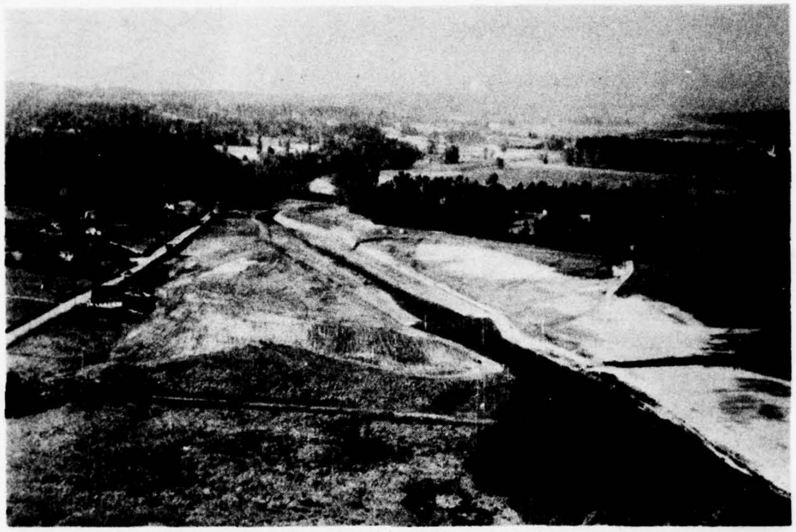


PHOTO 8-5. Sammamish River, October 1964. "Intake Transition" at outlet from Sammamish Lake, looking north upstream from Redmond. Foreground area is part of the King County Park. Redmond golf course just downstream.

residential area. Lake Sammamish State Park and a county park provide excellent opportunities for picnicking and water-oriented sports. The basin also contains numerous small lakes and streams with highly-developed shorelines.

The Sammamish River is the outlet for Lake Sammamish, flows 14 miles northwesterly through a valley approximately three-fourths mile wide, and discharges into the northern end of Lake Washington. The river is joined by Bear Creek (Redmond) and Bear Creek (Woodinville), and North and Swamp Creeks. These creeks drain uplands that are highly developed residential areas or logged off lands where urbanization is starting.

## Flood Plain

The Sammamish flood plain contains 3,600 acres of land in the 10-mile reach between Lake Sammamish and North Creek. Prior to lowering of Lake Washington in 1916, the Sammamish Valley was largely a swamp. As a result of lowering the lake and recent channel improvements, drainage has been improved and land use is rapidly changing from agricultural to residential and industrial. Downstream from North Creek, the river flows through a narrow valley with intermittent high banks. Numerous homes, some with private boat anchorages, occupy the riverbank in this reach. Backwater from Lake Washington provides sufficient depths for small pleasure boats as far upstream as Woodinville, about 5 miles above the river mouth.

Areas subject to inundation from major discharges are shown in Figure 8-1. A profile of the river is shown in Figure 8-2. Photos 8-5 through 8-7 show the Sammamish Valley in October 1964, during the final phases of channel improvement. The intake transition shown in Photo 8-5 is a low weir to control discharges from Lake Sammamish. Photos 8-6 and 8-7 show developments in 1964.

## History of Flooding

***Flood Characteristics.*** The streamflow of the Sammamish River is regulated by natural storage in Lake Sammamish. Flows generally begin to increase in October, reach a peak in February, and decrease to the minimum in August or September. Channel improvements completed in 1964 allow the passage of a much greater discharge with a relatively small rise in the level of the lake. Riverflow, even during major discharge, is not excessive and bank erosion is not a major problem.

Because the recent channel improvement changed streamflow characteristics, a summary hydrograph showing monthly discharges is not available. However, Figure 8-9 shows the probability of annual maximum flows at Bothell and reflects flow

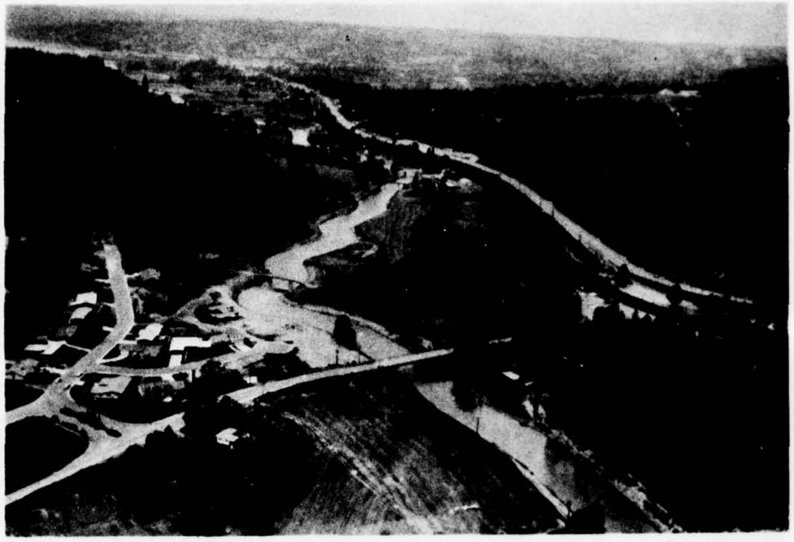


PHOTO 8-6. Sammamish River, October 1964. Looking west at Wayne Golf Course, 1 mile downstream from Bothell.

PHOTO 8-7. Sammamish River, October 1964. Looking northeast and upstream. City of Bothell on left.

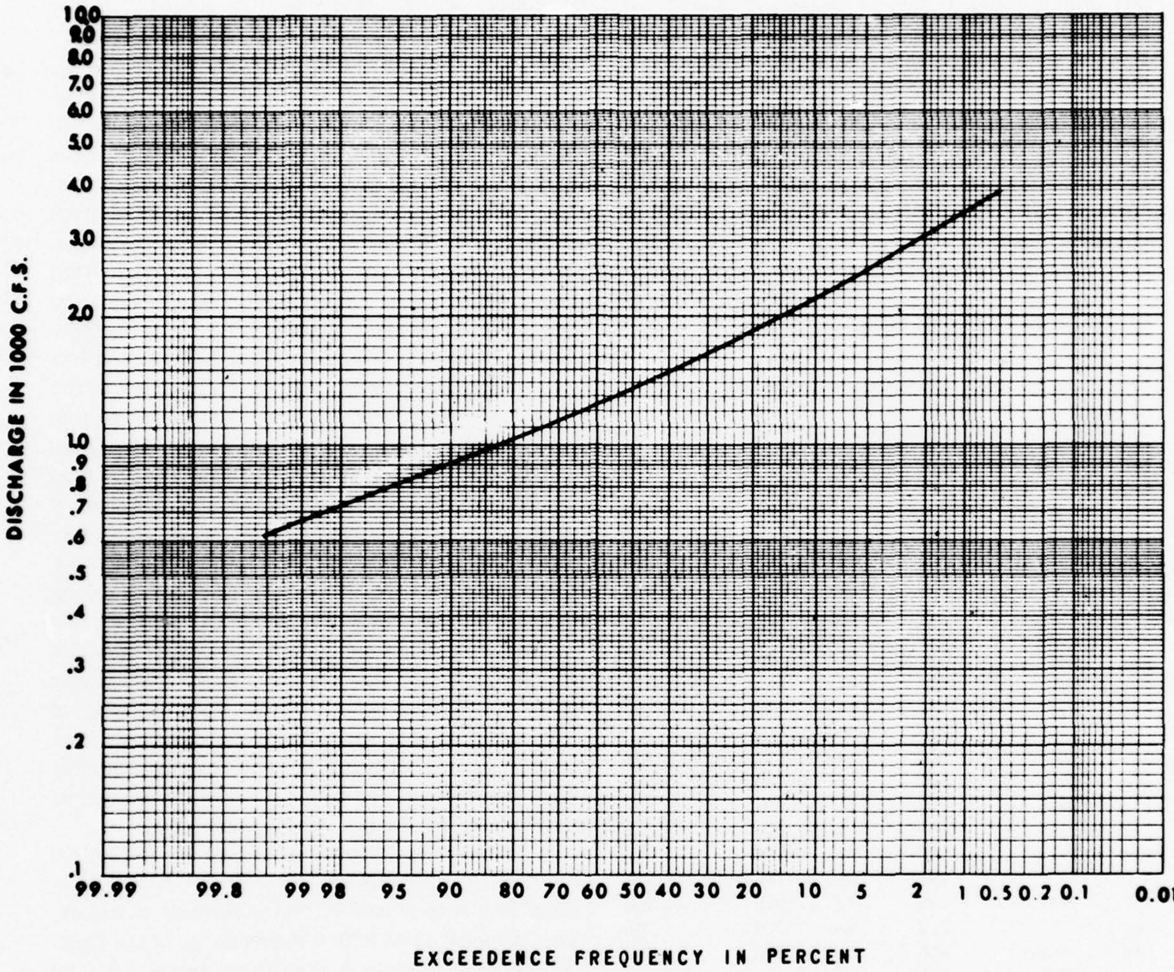



**FIGURE 8-9. Frequency curve of annual maximum peak flows, Sammamish River at Bothell**

conditions after the work was completed.

**Floods.** Prior to improving the Sammamish River channel, valley lands were flooded every winter. High runoff caused Lake Sammamish to rise considerably and resulted in varying degrees of damage to shoreline improvements. The highest lake elevation of record was 33.4 m.s.l. on 12 February 1951, when a discharge of 1,520 cfs was recorded at Redmond. Channel improvements largely prevent inundation from spring floodflows; however, when winter flows exceed 1,500 cfs near Redmond, water backs up into drainage ditches and results in shallow flooding of agricultural land.

Peak discharges recorded at the gaging station at Bothell are listed in Table 8-13. The gage measures flow from 88 percent of the basin.

**TABLE 8-13. Peak discharges—Sammamish River at Bothell**

| | | | |
|---|---|---|---|
| Dec 16, 1939 | 776 | Dec 31, 1949 | 791 |
| Jan 2, 1940 | 861 | Jan 10, 1950 | 879 |
| Mar 5, 8, 9, 1940 | 878 | Jan 22, 1950 | 1,600 |
| Jan 18, 1941 | 752 | Mar 5, 6, 1950 | 1,630 |
| Dec 23, 1941 | 1,030 | Mar 19, 1950 | 1,360 |
| Feb 4, 1942 | 701 | Dec 7, 1950 | 1,040 |
| Dec 30, 1942 | 778 | Jan 3, 1951 | 1,280 |
| Mar 28, 1943 | 872 | Jan 21, 1951 | 1,220 |
| Apr 25, 1944 | 510 | Feb 12, 1951 | 1,900 |
| Feb 8, 1945 | 922 | Feb 4, 1952 | 779 |
| Mar 22, 1945 | 808 | Feb 4, 1953 | 889 |
| Dec 7, 1945 | 751 | Nov 25, 1953 | 759 |
| Jan 8, 1946 | 956 | Dec 6, 1953 | 924 |
| Jan 24, 1946 | 861 | Dec 20, 1953 | 988 |
| Feb 6, 1946 | 1,070 | Jan 6, 1954 | 1,500 |
| Feb 28, 1946 | 1,050 | Feb 21, 1954 | 1,300 |
| Dec 16, 1946 | 1,090 | Nov 19, 1954 | 814 |
| Feb 2, 1947 | 1,290 | Dec 30, 1954 | 838 |
| Feb 14, 1947 | 1,130 | Feb 8, 1955 | 1,100 |
| Jan 8, 1948 | 1,210 | Apr 12, 1955 | 718 |
| Mar 22, 1948 | 956 | Dec 1, 1955 | 1,060 |
| May 6, 1948 | 715 | Dec 23, 1955 | 1,710 |
| May 29, 1948 | 899 | Jan 6, 1956 | 1,910 |
| Dec 9, 1948 | 813 | Mar 4, 1956 | 840 |
| Dec 31, 1948 | 993 | Feb 26, 1957 | 1,530 |
| Feb 10, 1949 | 924 | Jan 17, 1958 | 1,160 |
| Feb 17, 1949 | 1,360 | Jan 10, 25, 1959 | 1,400 |
| Feb 22, 1949 | 1,570 | Dec 15, 16, 1959 | 1,310 |
| Mar 19, 1949 | 901 | Feb 25, 1961 | 1,390 |

**Flood Damages.** The first detailed flood damage appraisal was completed in May 1940. Earlier appraisals were updated in 1967 prices and conditions. The estimated average annual flood damage was found to be $5,000, principally to agricultural lands.

## Existing Flood Control Measures

**Flood Forecasting and Warning.** The U.S. Weather Bureau provides forecasting services described in the Puget Sound Area Section of this appendix. As the relatively flat gradient of the Sammamish River permits a gradual rise to flood stage, no local warning system is required.

**Flood Protective Works.** A channel improvement project constructed in 1964 by the Corps of Engineers, in cooperation with King County, is the only flood control project in the Sammamish Basin. The river channel was widened and deepened from below Lake Sammamish to the Kenmore Bridge, which is approximately 2,000 feet upstream from Lake Washington. The improvement prevents all spring flood damages without causing Lake Sammamish to rise higher than elevation 29.0 m.s.l. A low weir with a crest elevation of 25.0 feet m.s.l. at the outlet of Lake Sammamish is capable of passing 1,500 cfs, including inflow from Bear Creek (Redmond). From Redmond to Woodinville, the channel capacity is 1,700 cfs. Below North Creek, the channel capacity is 1,900 cfs. A freeboard of about 3.5 feet throughout the improved reach was obtained by placing materials excavated from the channel along the tops of the riverbanks. This material is suitable for the base of future levees. The project provides 40-year protection against spring floods and 10-year protection against winter floods. Future closing of open drain ditches would result in a uniform levee system that would be capable of containing a 50-year flood estimated to be 2,200 cfs at the upper end of the channel and about 3,000 cfs near Bothell.

**Flood Plain Management.** Land acquisition for the channel improvement project included an easement on a strip of land 20 feet wide along each bank. The easement provides for maintenance of the channel by King County and restricts permanent construction on this land.

## Flood Problems

**Sammamish River and Lake Sammamish.** The flood problem along the Sammamish River consists of minor inundation of low agricultural lands. The lower lake levels resulting from the channel improvement project have benefited present homeowners on Lake Sammamish and flooding is minor. However, flooding could become a problem if the developers of new homesites do not take into consideration the variations in lake levels.

**Tributary Streams and Small Lakes.** Swamp, Bear and North Creeks originate in low hills north of Lake Washington, discharge into the Sammamish River, and are about 10 to 12 miles in length. Their watersheds have been mostly logged over and urbanization has started, primarily along Swamp Creek. The highest elevation in these watersheds is approximately 600 feet. The creeks have shallow channels, rather flat gradients and broad flood plains,and flood damage is significant.

Numerous small lakes provide choice homesites. Homes ring the shorelines of Silver, Martha, Cottage, Pine, Beaver and other lakes. Problems include flooding at variable lake levels, water supply, poor drainage, soils that are unsuitable for septic tanks and drain fields, and pollution.

Drainage problems along tributary streams and lakes are discussed in Appendix XIV, Watershed Management.

## PRESENT AND FUTURE NEEDS

### Evaluation of Present Situation

The Sammamish Valley is protected from major spring floods with a recurrence interval of once in 40 years and winter floods of a magnitude that can be expected to occur every 10 years. Low agricultural land in the flood plain is subject to minor flooding and erosion each winter; however, the economy of the basin is not seriously disrupted because primary transportation routes are not blocked and flooded lands are drained in a relatively short time.

The watersheds of small tributary streams have inadequate drainage channels and outlets, and flood damage is significant. Flooding and pollution are increasing as a result of rapid urban development.

### Flood Control Needs

**Prevention of Flood Damages** The Sammamish River flood plain does not suffer extensive flood damage. Average annual flood damages are estimated to be $5,000 and occur primarily to agricultural lands. Flood plain lands must be zoned to insure that future development of these lands is orderly and consistent with the protection provided.

Based on the methodology and considerations previously discussed for the Puget Sound Area, the flood damages are expected to increase by an annual compounded growth rate of 1-¼ percent. Future flood damages are estimated to be $6,000 in 1980, $8,000 in 2000 and $10,000 in 2020.

**Optimum Flood Plain Use.**

**Agriculture.** Farmland is being converted to residential and commercial use as a result of the expansion of the Seattle metropolitan area. The existing level of flood protection is adequate for the intensively farmed agricultural lands in the flood plain.

**Recreation.** The river itself is utilized for pleasure boating and fishing and some of the flood plain has been developed for golf courses. The establishment of additional recreational facilities along the river would enhance the recreational quality of the area and provide a more attractive environment for surrounding residential areas.

**Intensive Land Use.** Residential and commercial developments are encroaching on the flood plain along the entire river. Flood damages can be expected to increase unless additional flood protection is provided or zoning and regulation of the flood plain is implemented.

### Summary of Flood Control Needs

The present channel and levee system provide adequate protection for an agriculturally or recreationally oriented flood plain. If intensive urban and industrial development of the flood plain is desired, a one-hundred year level of flood protection should be provided.

## MEANS TO SATISFY NEEDS

### Flood Control Objectives

The ultimate flood control objectives for the Sammamish River Basin should be to have 100-year protection for the entire flood plain downstream of Lake Sammamish. Regulations should be adopted which will restrict developments to those compatible with the degree of flood protection provided.

### Opportunities for Structural Measures

**Upstream Storage.** The streamflow of the Sammamish River is primarily dependent upon lake levels and outflow from Lake Sammamish. Increased flood protection could be provided by flood control storage in Lake Sammamish.

**Levee and Channelization.** Increased flood control could be provided by levee and channel improvements.

## Constraints

**Open Space.** Local interests may elect to keep the flood plain as open space to be used for agriculture and recreational purposes such as parks, golf courses, etc. If this occurs the existing flood protection will be adequate.

## Solution to Flood Control Needs

**General.** A control structure at the outlet of Lake Sammamish and levees in combination with flood plain management are the nucleus of the flood control plan in the Sammamish River Basin. The flood control plan shown in Table 8-14 and on Figure 8-8 would provide for optimum development of the flood plain.

**Sequence of Development.**

**To 1980.** Flood plain management would be required. The flood plain should be zoned to restrict developments until adequate protection is provided.

**1980-2020.** Demand for change in use of the flood plain lands to industrial and residential use may require additional flood protection. A control structure at the outlet of Lake Sammamish and minor levee and channel improvements along the Sammamish River could provide a 100-year level of protection.

**Accomplishments.** The present degree of flood control is adequate for intensive agricultural utilization of the flood plain. Additional flood control protection can be provided by levee construction and flood control storage in Lake Sammamish and could provide the entire 3,600 acre flood plain with protection in excess of 100 years. This additional protection may be required prior to the year 2020 if flood plain lands are used for urban or industrial expansion. Flood plain regulation should be implemented to insure that future development is consistent with the protection provided.

**Alternatives Considered.** Providing upstream storage in tributary streams to Lake Sammamish and the Sammamish River was evaluated and determined to be economically infeasible.

Floodproofing of existing buildings was evaluated as an alternative to major flood protective works. The major part of the estimated $5,000 average annual flood damages occur to agricultural lands. Floodproofing may have limited application but would not provide for optimum development of the Sammamish Basin flood plain.

## Summary

The flood problem in the 3,600 acre Sammamish River flood plain consists of minor inundation of agricultural lands. The Sammamish valley is protected from major spring floods with a recurrence interval of once in 40 years and winter floods of a magnitude that can be expected to occur once every 10 years. Average annual flood damages are estimated to be $5,000 based on 1966 prices and conditions and are expected to increase to $6,000 in 1980, $8,000 in 2000, and $10,000 in 2020.

The present degree of flood protection is adequate for agricultural utilization of the flood plain. Protection in excess of 100 years can be provided by implementation of the flood control plan if urban and industrial utilization of the flood plain is determined to be desirable.

**TABLE 8-14. Flood control plan**

| Flood Control Feature | Design Capacity cfs | Effective Flood Control Storage acre-feet | Sequence of Development to 1980 | to 2000 | to 2020 | Estimated Development Costs for Projects Based on January 1968 Costs |
|---|---|---|---|---|---|---|
| Flood Control Storage | | | | | | |
| Lake Sammamish Control Structure | | 6,000 | | | X | $1,000,000 |
| Levee and Channel Improvements | | | | | | |
| Lake Sammamish to Lake Washington | 3,000 | | | | X | 2,000,000 |
| Flood Plain Management | | | X | X | X | 17,000[1] |
| Total Cost of Plan | | | | | | $3,017,000 |

[1]Includes estimated cost of a Flood Plain Information Study and flood plain zoning and regulation implementation costs.

# GREEN RIVER BASIN

## PRESENT STATUS

### Stream System

The Green River Basin is about 50 miles long, has a maximum width of 15 miles, and covers an area of 483 square miles. The river originates on the western slopes of the Cascade Mountains near Stampede Pass, flows westerly about 50 miles to Auburn, thence northwesterly for 32 miles, and discharges into Elliott Bay at Seattle. The lower 12-mile reach of this stream is known as the Duwamish River. The lower 6 miles of the Duwamish are navigable. Minor tributaries also flow into the Green River. Principal streams are Big Soos, Newaukum, and Mill Creeks, and the Black River.

### Flood Plain

The flood plain of the Green River contains approximately 22,700 acres of land. The area subject to flooding is shown on Figure 8-1. Upstream from Auburn, the valley is very narrow and the river follows a well-defined course. From Auburn to its mouth at Elliott Bay, the river follows a meandering course through a valley that varies from one to two miles in width.

Developments in the flood plain include the cities of Renton, Kent, Auburn, and Tukwila. The lower 5 miles contain considerable port and industrial development in Seattle. The flood plain upstream from the industrial area contains about 17,577 acres which is zoned as follows: industrial and commercial, 7,948 acres; agricultural, 7,496 acres; residential, 2,043 acres; and parks, 110 acres. About 12,000 acres of this area are still utilized for agriculture. The areas zoned for industrial, commercial and residential uses are forecasted to be fully occupied within the next 20 to 25 years. Thereafter, agricultural land probably will be converted to these uses.

The availability of low cost electric power, the deep water ports and abundant fresh water, have influenced rapid industrial development in the basin. Employment in aerospace aircraft and parts manufacturing is significant. There is a high level of activity in shipbuilding, machinery, primary metals and fabricated metal manufacturing. About 175,000 tons of coal are mined each year. Agriculture is of commercial importance; however, land use is changing from agricultural to industrial, commercial and residential.

Heavy expenditures are being made for State and interstate highways, port and airport facilities, to accommodate rapid industrial expansion. The Green River is an important spawning ground for anadromous fish. The principal spawning areas are the Green River above Auburn and Big Soos Creek, where the State of Washington operates a fish hatchery.

The city of Tacoma utilizes the upper watershed for water supply and access is restricted above the intake structure. The intake is approximately 6 miles upstream from Palmer and 3 miles downstream from Howard A. Hanson Dam.

### History of Flooding

**Flood Characteristics.** High flows in the fall or winter coincide with maximum precipitation. A secondary peak occurs when rising temperatures melt the accumulated snowpack in the mountains. Figure 8-10 shows the runoff pattern for the Green River near Palmer. Figure 8-11 is the daily discharge hydrograph for the Green River near Auburn.

**Floods.** All of the major floods in the Green River Basin have occurred during the period November through March. Photo 8-8 is a view of serious erosion caused by the flood of December 1959. Table 8-15 lists estimated and recorded discharges exceeding 12,000 cfs.

Zero damage flow measured at Auburn is estimated to be 9,000 cfs. Flooding begins at this flow because high water levels in the Green River prevent drainage of adjacent flood plain lands. Howard A. Hanson Dam, completed in March 1962, regulates riverflows and is capable of reducing discharges to 12,000 cfs at Auburn.

**Flood Damages.** Prior to 1962, flood damages in the flood plain averaged $600,000 annually. Since completion of the Howard A. Hanson Project in March 1962, overbank flooding has been substantially eliminated and average annual flood damages have been reduced to approximately $325,000. High stages on the Green River prevent the Black River and Mill Creek from discharging into the main river and backflow results in severe flooding in these areas. Photos 8-9 and 8-10 are scenes of flooding caused by backflow during the flood of February 1965.

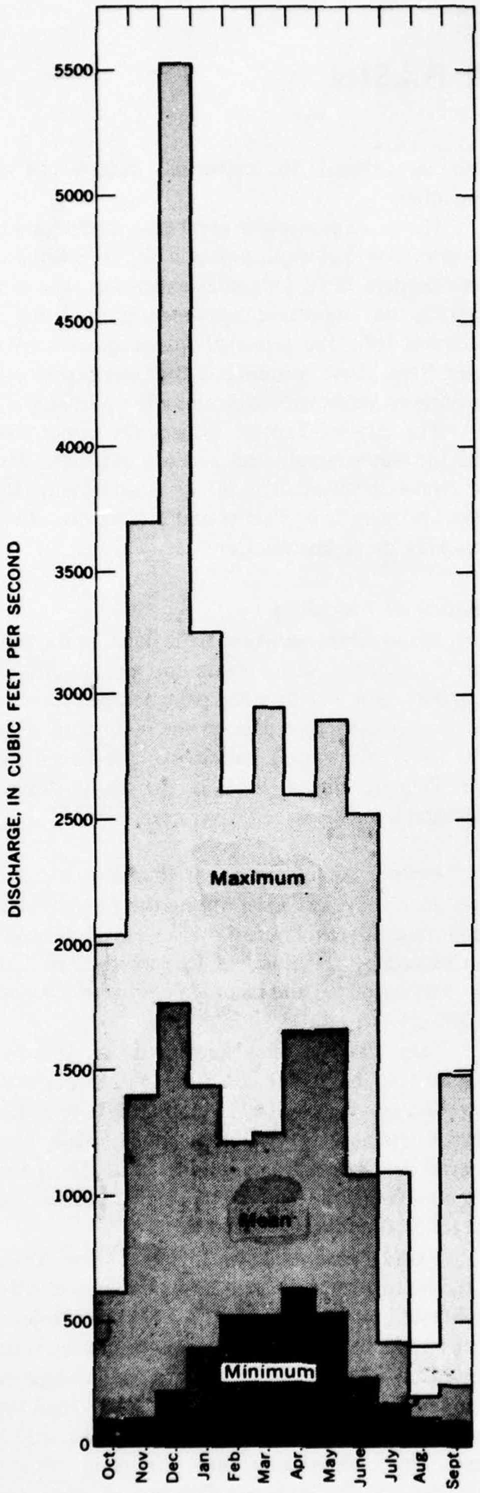



FIGURE 8-10. Maximum, mean and minimum monthly discharges, Green River near Palmer, 1931-60.

**TABLE 8-15. Discharges exceeding 12,000 cfs.**

| Date | Near Palmer Second-feet | Near Auburn Second-feet |
|---|---|---|
| 11 January 1932 | 15,100 | |
| 26 February 1932 | 17,400 | |
| 13 November 1932 | 14,900 | |
| 8 January 1933 | 13,000 | |
| 3 November 1933 | 13,000 | |
| 9 December 1933 | 21,700 | |
| 22 December 1933 | 17,800 | 24,000 estimated |
| 23 January 1934 | 14,500 | |
| 25 October 1934 | 13,400 | |
| 18 April 1938 | 13,200 | 14,400 |
| 3 December 1943 | 14,600 | 12,900 |
| 7 January 1945 | 13,600 | 13,600 |
| 29 December 1945 | | 12,800 |
| 11 December 1946 | 23,200 | 22,000 |
| 9 February 1951 | 14,500 | |
| 10 February 1951 | | 18,400 |
| 23 January 1953 | 12,700 | |
| 31 January 1953 | 12,300 | |
| 1 February 1953 | | 13,400 |
| 9 December 1953 | 17,600 | |
| 10 December 1953 | | 18,300 |
| 8 February 1955 | 14,100 | 15,500 |
| 11 December 1955 | 18,300 | |
| 12 December 1955 | | 20,300 |
| 10 December 1956 | 14,500 | 13,900 |
| 12 November 1958 | 15,800 | |
| 13 November 1958 | | 15,900 |
| 23 November 1959 | 27,800 | 28,100 |
| 15 December 1959 | 14,300 | 15,500 |
| 21 February 1961 | 12,100 | 13,000 |
| 29 January 1965 | | 11,400[1] |

[1] Includes effect of regulation by Howard A. Hanson Dam.

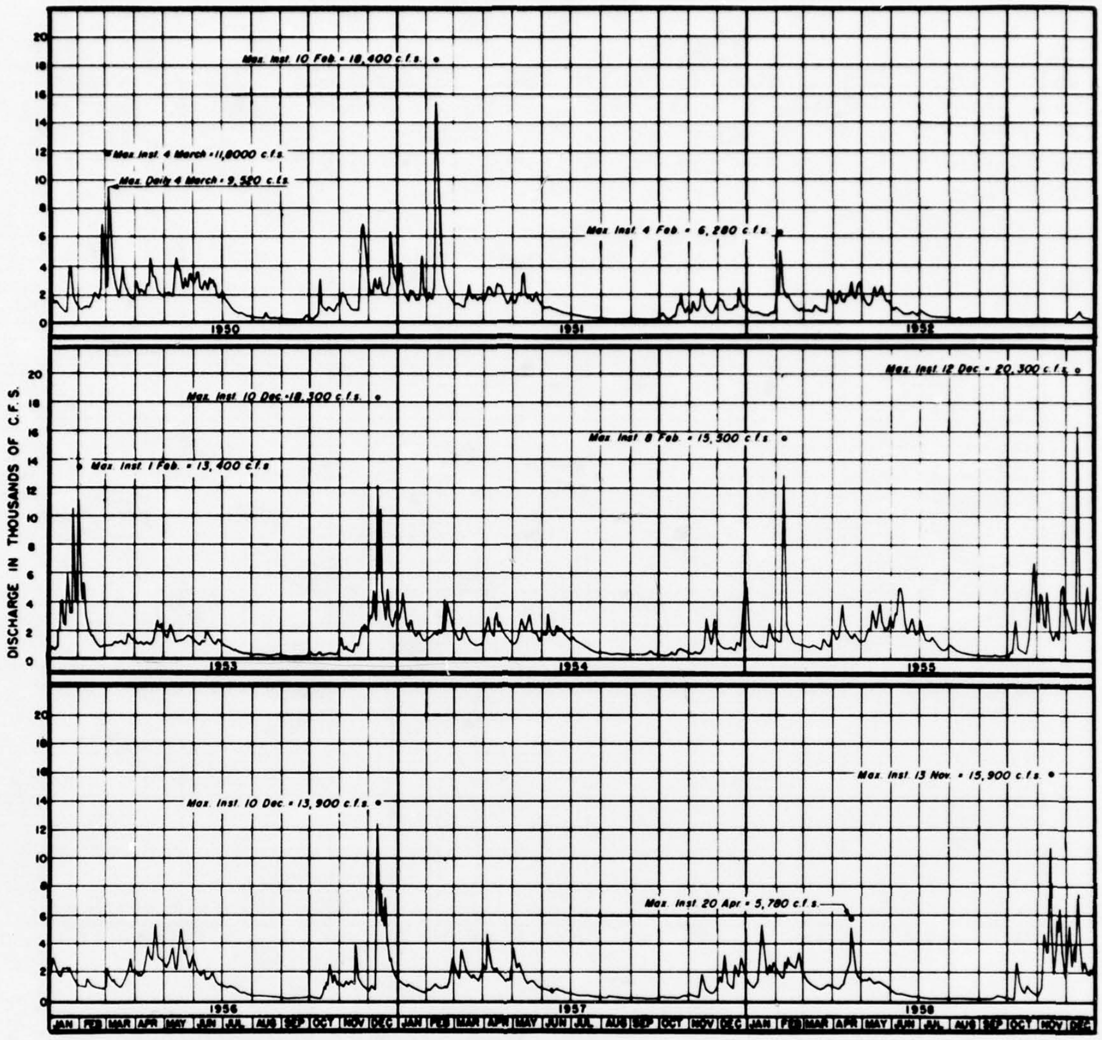



**FIGURE 8-11. Daily discharge hydrograph, Green River near Auburn.**

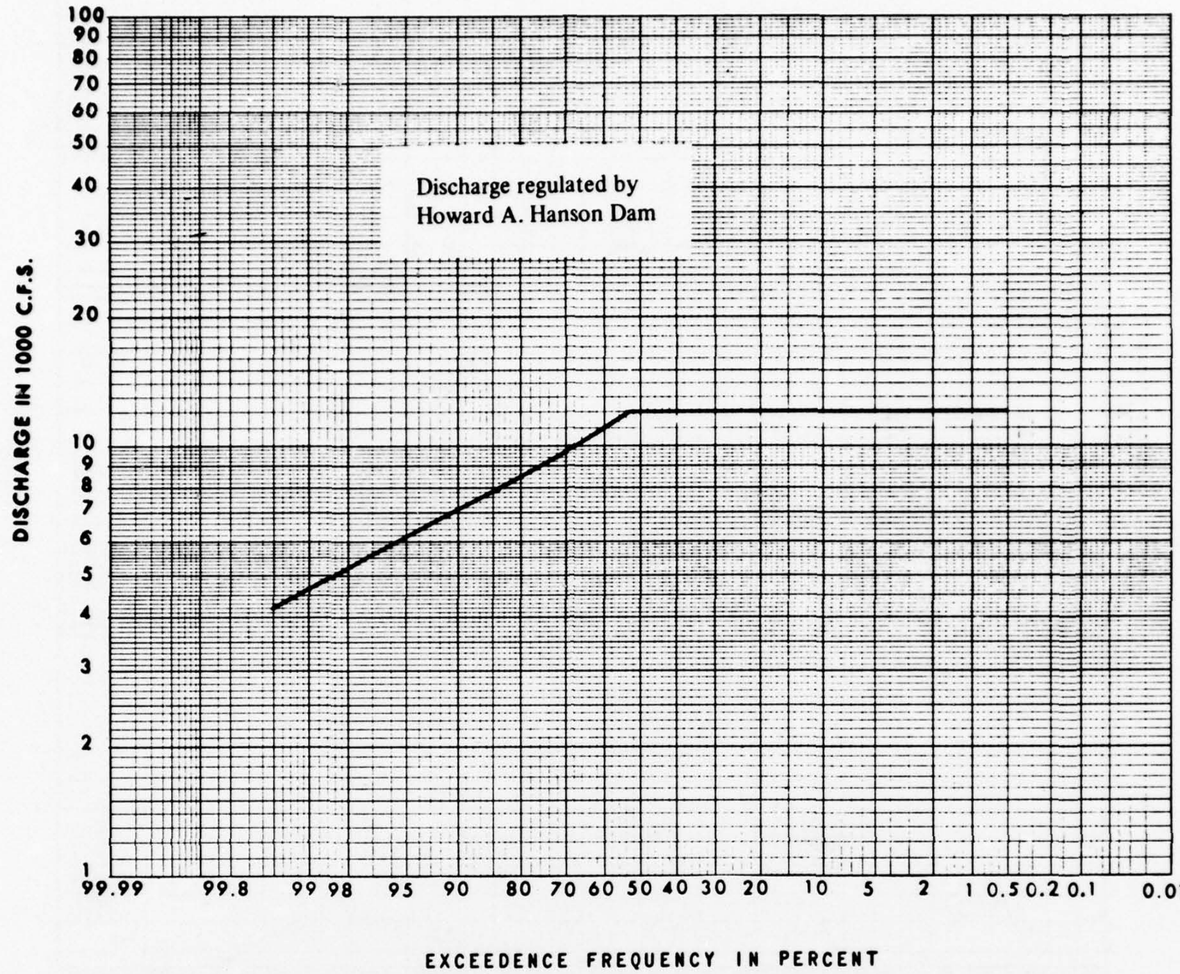



**FIGURE 8-12. Frequency curve of annual maximum peak flows, Green River near Auburn**

PHOTO 8-8. Erosion caused by levee break at Russell Road east of Kent, Washington.

PHOTO 8-9. Flooding caused by backflow in Black River near Longacres Racetrack near Renton, Washington, February 1965.

PHOTO 8-10. Flooding of Mill Creek bridge caused by backwater from the Green River, February 1965.

PHOTO 8-11. Shows bankfull of Green River at river mile 17.6, February 1965. Brisco School in right center.

During the February 1965 flood, the channel downstream from Auburn was bankfull for five days and the freeboard was reduced to zero, as shown in Photo 8-11. Expenditures for channel and levee repairs totaled about $230,000. However, controlled releases by the Howard A. Hanson Project prevented an estimated $4,200,000 in flood damages by reducing the natural peak discharge of 24,000 cfs to 11,400 cfs at Auburn.

### Existing Flood Control Measures

**Flood Forecasting and Warning.** The U.S. Weather Bureau provides the flood forecasting services described in the Puget Sound Area Section of this appendix.

King County has established a flood fighting procedure to maintain a channel capacity of 11,000 cfs downstream from Auburn. During high riverflows, employees of the County Engineer's Department patrol the levees and perform emergency work as required. If the levees fail, efforts are then concentrated on minimizing damages to personal property.

**Flood Protective Works.**

**Levees.** Approximately 11.4 miles of levees have been constructed, primarily downstream from Kent. The locations of these levees are shown on Figure 8-1.

**Bank Protective Works.** Since the adoption of enabling legislation by the State of Washington in 1945, the State and King County have shared reaches of the Green River to control riverbank erosion.

**Channel Improvements.** The only extensive channel improvement is the Duwamish Waterway in Seattle. The waterway is a deep draft navigation channel that extends 6 miles upstream from Elliott Bay. The channel and turning basins are dredged periodically.

**Upstream Storage.** Howard A. Hanson Dam, a Corps of Engineers flood control project, is approximately 32 miles upstream from Auburn. This project controls floods with a recurrence interval in excess of 100 years. A conservation pool is maintained during the summer months to augment low flows to a minimum of 110 cfs for the benefit of the fish resources and pollution abatement.

**Flood Prevention and Watershed Protection.** The Soil Conservation Service, in cooperation with local interests, is planning two drainage and flood control projects under the authority of Public Law 566. One project will extend from the mouth of the Black River to Kent east of the Green River; the other will include the west side of the valley. These projects will provide 58 miles of new and improved drainage channels, complete with outlet works and pumping plants, and provide 100-year protection from internal flooding. The combined capacity of the flood gates is 5,200 cfs and that of the pumping plants 4,000 cfs.

**Flood Plain Management.** No ordinances have been adopted to control development in the flood plain. However, the Corps of Engineers has established the Flood Plain Management Service described in the Puget Sound Area Section of this appendix.

### Flood Problems

**Lower Green River.** Very little development is subject to flood damage upstream from Auburn and flooding is minor. Below Auburn, damage is confined mostly to flooding at the mouths of tributary streams and bank erosion. However, high stages on the Green River prevent the Black River, Mill Creek and other small tributaries from discharging into the main river and backwater inundates commercial, industrial and residential developments and transportation facilities. Poor interior drainage also contributes to inundation of the flood plain during heavy rainfall. Maximum controlled releases by the Howard A. Hanson Project reduce the freeboard in this reach to zero. Discharges by drainage projects under construction will increase riverflow.

**Tributary Streams.** Most of the upper watershed is commercial forestland owned by the city of Tacoma and is the source of the city's water supply. An 1,100-acre area northwest of Enumclaw is subject to overbank flows and siltation from Newaukum and Coal Creeks. The area is predominantly in dairy farms and most of the land is in pasture. King County and local interests have required a Public Law 566 project to resolve drainage and flood problems.

## PRESENT AND FUTURE NEEDS

### Evaluation of Present Situation

The Howard A. Hanson Project, levees, and bank stabilization and protective works prevent major flooding in the Green River Valley.

The Howard A. Hanson Project is capable of reducing flood discharges at Auburn to 12,000 cfs for floods with a recurrence interval in excess of once in 100 years. Below Kent, levees are generally adequate

to contain this flow; however, the channel is bankfull and the freeboard is zero. Erosion during sustained high flows is severe, and emergency action is required to prevent levee failures during floodflows. Runoff from drainage projects under construction will increase riverflow and could result in overbank flows unless additional channel capacity is provided.

### Flood Control Needs

**Prevention of Flood Damages.** In the Green River flood plain below Auburn the average annual flood damages are estimated to be $325,000. These damages are largely to agricultural lands and industrial and residential developments and result mainly from local inflow problems. Future developments in the flood plain should be planned to insure adequate protection against this type of flooding. The current plans to provide improved drainage to flood-prone lands may result in decreased overall protection for the flood plain since additional water will be discharged into the river. Additional protective measures may be required as a result.

Based on the methodology and considerations previously discussed for the Puget Sound Area, the flood damages are expected to increase by an annual compounded growth rate of 4 percent. Future flood damages are estimated to be $570,000 in 1980, $1,250,000 in 2000, and $2,760,000 in 2020.

**Optimum Flood Plain Use.**

**Agriculture.** Expansion of the Seattle-Tacoma metropolitan area will require the conversion of farmland to industrial, residential and commercial purposes.

**Recreation.** Recreation will continue to be an important water use along the Green River. Public access is assured by existing easements and public access areas and by the continuing State of Washington access procurement program.

**Intensive Land Use.** A major industrial corridor is expected to occupy the Green River Valley between the city of Seattle and the King-Pierce County line. Residential developments can be expected to occupy the surrounding hillsides.

### Summary of Flood Control Needs

Additional protection from flooding will be required in the future to maintain the existing high level of flood protection. As drainage is provided to flood plain and adjacent lands, additional channel capacity will be required to accommodate this increased inflow. Because of the intensive industrial and urban use of flood plain lands, a level of protection in excess of 100 years should be provided to the entire flood plain area.

## MEANS TO SATISFY NEEDS

### Flood Control Objectives

The flood control objective is to provide the level of flood protection consistent with present and future land use. The lower Green River Valley flood plain is becoming and will continue to be highly industrialized and flood protection in excess of 100 years should be provided.

### Opportunities For Structural Measures

**Storage.** Howard A. Hanson Dam provides a high level of flood protection to the Green River flood plain. However, additional storage is possible at sites located upstream from Hanson Dam. These sites include Sunday and Smay Creeks and on the main river at Weston (see Appendix III, Hydrology and Natural Environment for location).

**Levees and Channelization.** Flood control by major levee construction is effective for protection of the industrial areas along the lower Green River. The entire flood plain from Auburn downstream is expected to become industrialized or urbanized and could be provided additional protection by levees and channelization.

**Diversion.** Diversion of peak flood discharges of the Green River could be accomplished by diversion at river mile 22 into Puget Sound by means of a pumping plant, one mile of tunnel, and one mile of open channel.

### Solutions to Flood Control Needs

**General.** Storage at Howard A. Hanson Dam, together with levees and channel improvements and flood plain management, are the components of this plan. The flood control plan would provide for optimum development and protection for the flood plain lands to 2020. Prevention of flooding from interior drainage is discussed in Appendix XIV.

**Sequence of Development.**

**To 1980.** Levee and channel improvements along both banks of 16 miles of the Green River below Auburn to contain flows of 12,000 cfs with three feet of freeboard could be constructed. Existing

levees could be set back and the channel widened as required. This increased channel capacity would accommodate the controlled releases of 12,000 cfs from Howard A. Hanson Dam and the inflow resulting from interior drainage pumping plants. Flood plain zoning and regulation should be provided. The levee and channel improvements are estimated to cost $12,000,000, based on January 1968 prices. Implementation of flood plain management is estimated to cost $10,000. No additional flood protective measures are anticipated after 1980.

**Economic Analysis for 1980 Level of Flood Control.** Annual benefits for the flood control plan are $723,000 and annual costs are $650,000 based on 1966 prices. Annual costs include interest and amortization of the total investment (including interest during construction), and average annual costs of operation and maintenance. An interest rate of 4-5/8 percent was used to compute interest during construction; the present worth of future costs; and the annual cost of interest and amortization. An economic life of 50 years was used for levee construction.

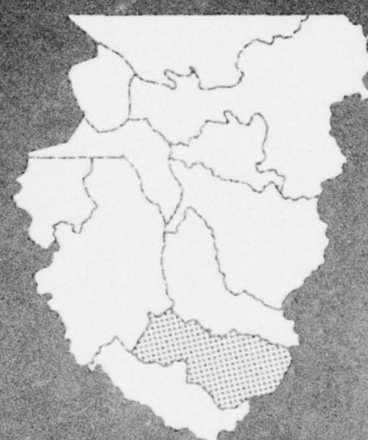
**Accomplishments.** The entire 22,700-acre flood plain below Auburn would be protected against floods in excess of 100 years.

**Alternatives Considered.** Additional storage by raising Howard A. Hanson Reservoir or constructing additional storage upstream at Weston and on Sunday Creek and Smay Creek was considered; however, economic feasibility of such storage was found to be lacking. Diversion of flood waters from the basin was considered and found to lack economic feasibility.

## Summary

Howard A. Hanson Dam controls flood discharges to 12,000 cfs on the Green River near Auburn. Proposed interior drainage and pumping facilities are expected to increase flows. Increased channel capacity to 12,000 cfs in the river reach below Auburn is required prior to 1980. This additional channel capacity could be provided by channel improvements and levee construction. In conjunction with the Public Law 566, the interior drainage project would provide protection against main stem floods with a recurrence interval in excess of 100 years and small tributary floods with a recurrence interval of 100 years. Flood plain regulation and management along with an efficient flood warning and fighting system would also be an essential part of this flood plan for the Green River Basin.

# Puyallup Basin



# PUYALLUP BASIN

## DESCRIPTION OF BASIN

The Puyallup River Basin, Figure 9-1, is 50 miles long, 30 miles wide at the widest part, and covers about 1,254 square miles almost entirely within Pierce County. The basin is bounded on the north by the Cedar and Green River Basins, on the east by the crest of the Cascade Mountains, on the south by the Nisqually River Basin, and on the west by Puget Sound.

The Puyallup River drains an area of 972 square miles. The largest tributary, the White River, joins the Puyallup at Sumner. In their lower courses, both rivers flow across extensive glacial plains where the bedrock is deeply buried. Profiles of the Puyallup and its tributaries are shown in Figure 9-2.

The Snoqualmie National Forest and Mount Rainier National Park occupy the eastern half of the basin, and the higher elevations are predominantly woodlands. Agricultural activities are centered primarily in the rich, alluvial lowlands downstream from Orting and Auburn.

The most outstanding geologic feature is Mount Rainier, a dormant volcano that rises to an elevation of 14,410 feet above mean sea level. Granitic rock is commonly found on the eastern side of the mountain and volcanic rocks, mainly basalts, form the sharp peaks and serrated ridges on the northwest. The foothills from Fairfax to South Prairie contain large deposits of coal.

The climate is mild in the winter and cool in the summer. Average mean annual temperatures vary from 37° F at Paradise Inn on Mount Rainier to 52° F at Tacoma. The mean annual precipitation varies from 106 inches at Paradise Inn to 35 inches at Tacoma, with about 80 percent falling from October to March.

Urban development in the Puyallup Basin has been greatly affected by the rapidly expanding Seattle-Tacoma metropolitan area. Built up areas are primarily located in the western part of the basin which contains the majority of the population. Table 9-1 gives the historic population figures for the Puyallup Basin and principal communities. The population of the basin increased from 174,600 in 1940, to 364,400 in 1967. About half of the population in the basin lives in and near Tacoma.

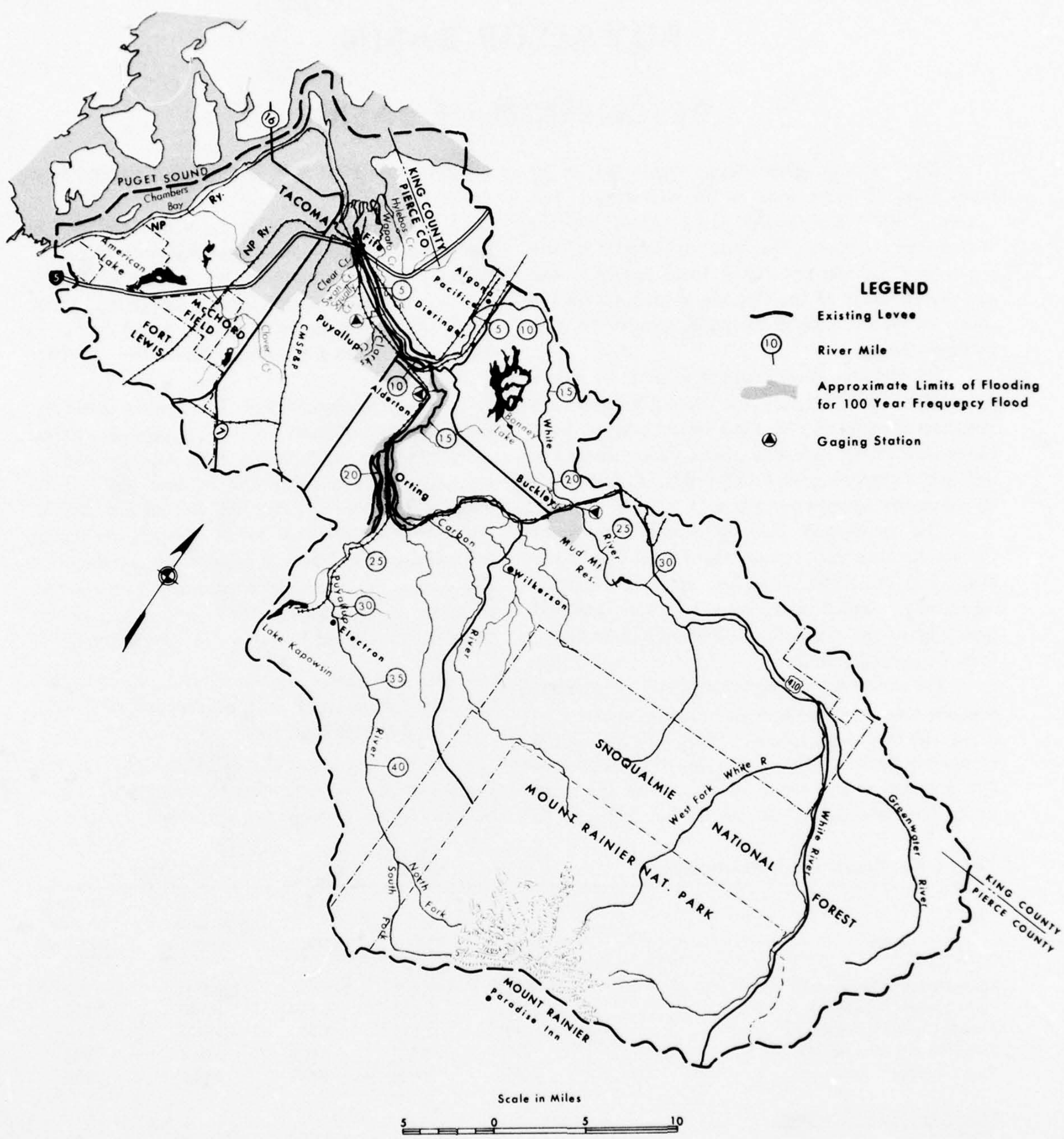
Natural resources in the Puyallup Basin include rich river bottomland, timber, a deepdraft salt water harbor and recreational areas.

Employment for the Puyallup Basin is best demonstrated by Pierce County data, Table 9-2, as statistics for the basin are not available.

**TABLE 9-1. Population—past and present**

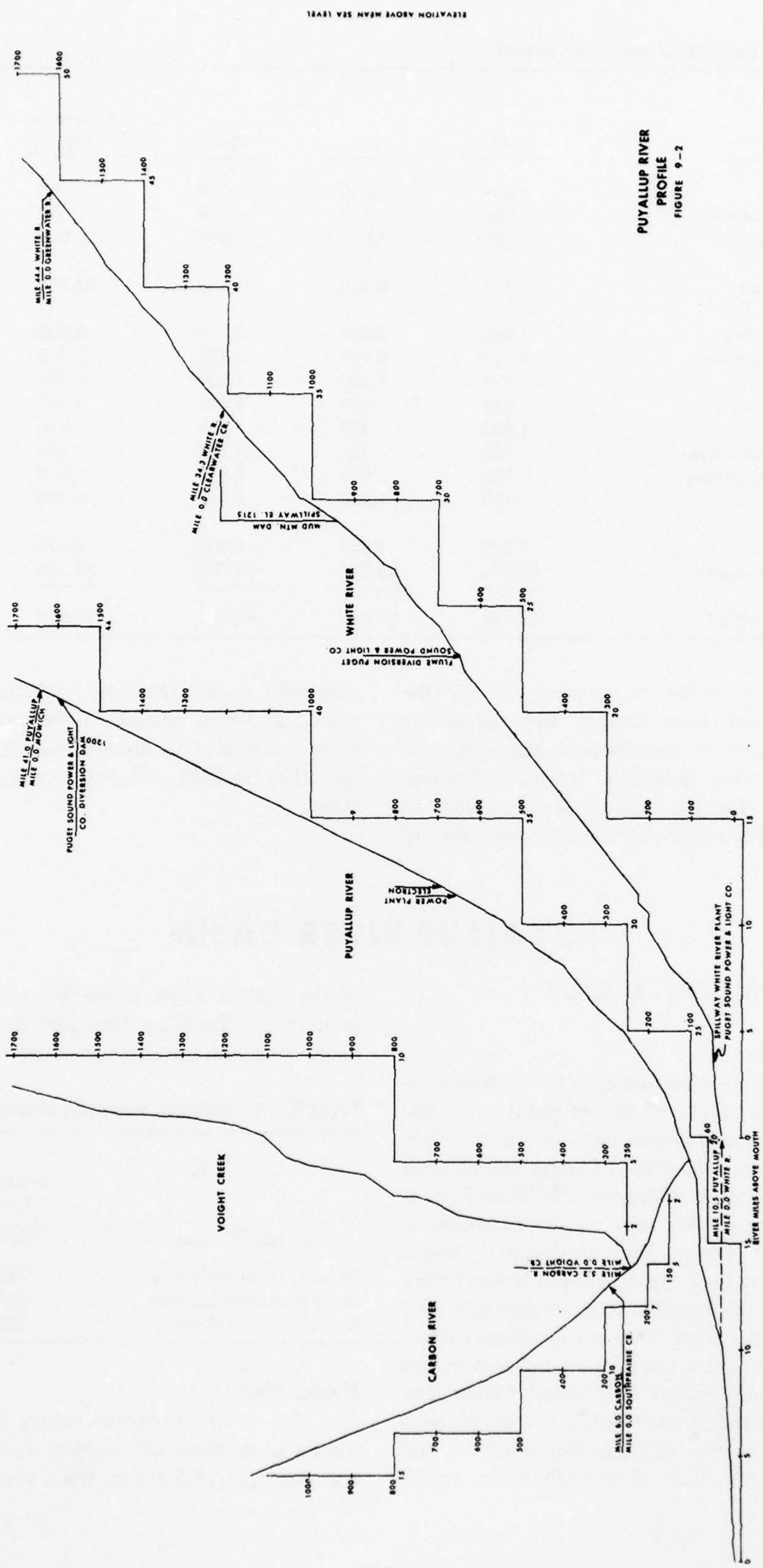
| Area | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| United States (thousands) | 132,164 | 151,326 | 179,323 | 200,000 | 52 |
| Puget Sound (thousands) | 1,007 | 1,418 | 1,768 | 2,100 | 110 |
| Central Division (thousands) | 820 | 1,196 | 1,513 | 1,751.2 | 114 |
| Pierce County (thousands) | 182.1 | 275.9 | 321.6 | 378.3 | 108 |
| Puyallup Basin (thousands) | 174.6 | 264.6 | 308.4 | 349.8 | 100 |
| Cities and Towns in the Basin | | | | | |
| Tacoma | 109,410 | 143,700 | 148,000 | 156,000 | 43 |
| Puyallup | 7,890 | 10,010 | 12,060 | 14,200 | 80 |
| Sumner | 2,140 | 2,820 | 3,160 | 3,950 | 85 |
| Buckley | 1,170 | 2,700 | 3,540 | 3,650 | 212 |
| Milton | 670 | 1,370 | 2,220 | 2,600 | 288 |
| Orting | 1,210 | 1,300 | 1,520 | 1,600 | 32 |

*Figures are from U.S. Census Report; Seattle Area Industrial Council, 1967, and Appendix IV, Economics.*




**PUYALLUP BASIN**

**FIGURE 9-1. Flood plain and existing protective works**




PUYALLUP RIVER
PROFILE
FIGURE 9-2

TABLE 9-2. Employment—past and present

| Industry | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| Agriculture | 3,937 | 3,656 | 2,738 | 1,860 | (-53) |
| Forestry, Fishing, Mining | 586 | 787 | 359 | 60 | (-90) |
| Contract Construction | 3,383 | 6,531 | 6,532 | 6,510 | 92 |
| Manufacturing Total | 16,407 | 18,310 | 21,858 | 23,360 | 42 |
| Food and Kindred Prod. | 1,966 | 2,631 | 3,278 | 3,300 | -- |
| Lumber, Wood and Furn. | 8,723 | 8,297 | 5,536 | 6,700 | -- |
| Paper & Allied Prod. | 724 | 1,200 | 1,930 | 1,900 | -- |
| Chem. & Allied Prod. | 574 | 680 | 1,084 | 1,200 | -- |
| Fabricated Metal | 1,408 | 377 | 808 | 470 | -- |
| Mach. (Elect. & Non-Elect.) | 208 | 301 | 1,106 | 900 | -- |
| Transportation Equipment | 791 | 975 | 3,572 | 1,570 | -- |
| Primary Metals | 475 | 1,938 | 1,499 | 1,100 | -- |
| All Other | 1,538 | 1,920 | 3,045 | 6,020 | 291 |
| Non-Commodity Industry | 39,046 | 53,744 | 64,886 | 84,760 | 117 |
| TOTAL EMPLOYMENT | 63,359 | 83,037 | 96,373 | 116,550 | 84 |

In recent years the employment trend of the basin has shifted from timber and agriculture orientated industries to metallurgical, chemical, shipbuilding, and service industries. Industrial development, mainly in Tacoma, includes an oil refinery, an aluminum reduction plant, several large saw mills and pulp mills, several chemical products manufacturing plants, a copper smelter, a ferro-alloy plant, and industries related to aircraft manufacturing. Mining operations include coal, basalt rock, clay and sandstone.

# PUYALLUP RIVER BASIN

## PRESENT STATUS

### Stream System

The Puyallup River emerges from glaciers on the southwestern slopes of Mount Rainier and discharges into Commencement Bay, an arm of Puget Sound, at Tacoma. The White, Carbon and Mowich Rivers are the principal tributaries. The White River is a glacier-fed stream that rises on the northeastern slopes of Mount Rainier, flows northwesterly and is joined by its West Fork and Clearwater Rivers before discharging into the Puyallup River at river mile 10.5 near Sumner. The Carbon River emerges from Carbon Glacier on the northern slopes of Mount Rainier, and empties into the Puyallup River below Orting. The Mowich River is fed by the North and South Mowich Glaciers on the western slopes of Mount Rainier, and enters the Puyallup River 22 miles above the mouth of the Carbon River. Table 9-3 gives the drainage areas of the Puyallup River and its principal tributaries along with their average annual discharges.

TABLE 9-3. Drainage areas and average annual runoff

| River | Drainage Area (Sq. Mi.) | Average Annual Runoff (Acre-Feet) |
|---|---|---|
| Puyallup River at Puyallup | 948 | 2,490,000 |
| White River near Buckley | 401 | 1,080,000 |
| Carbon River at Mouth | 230 | 740,000 |

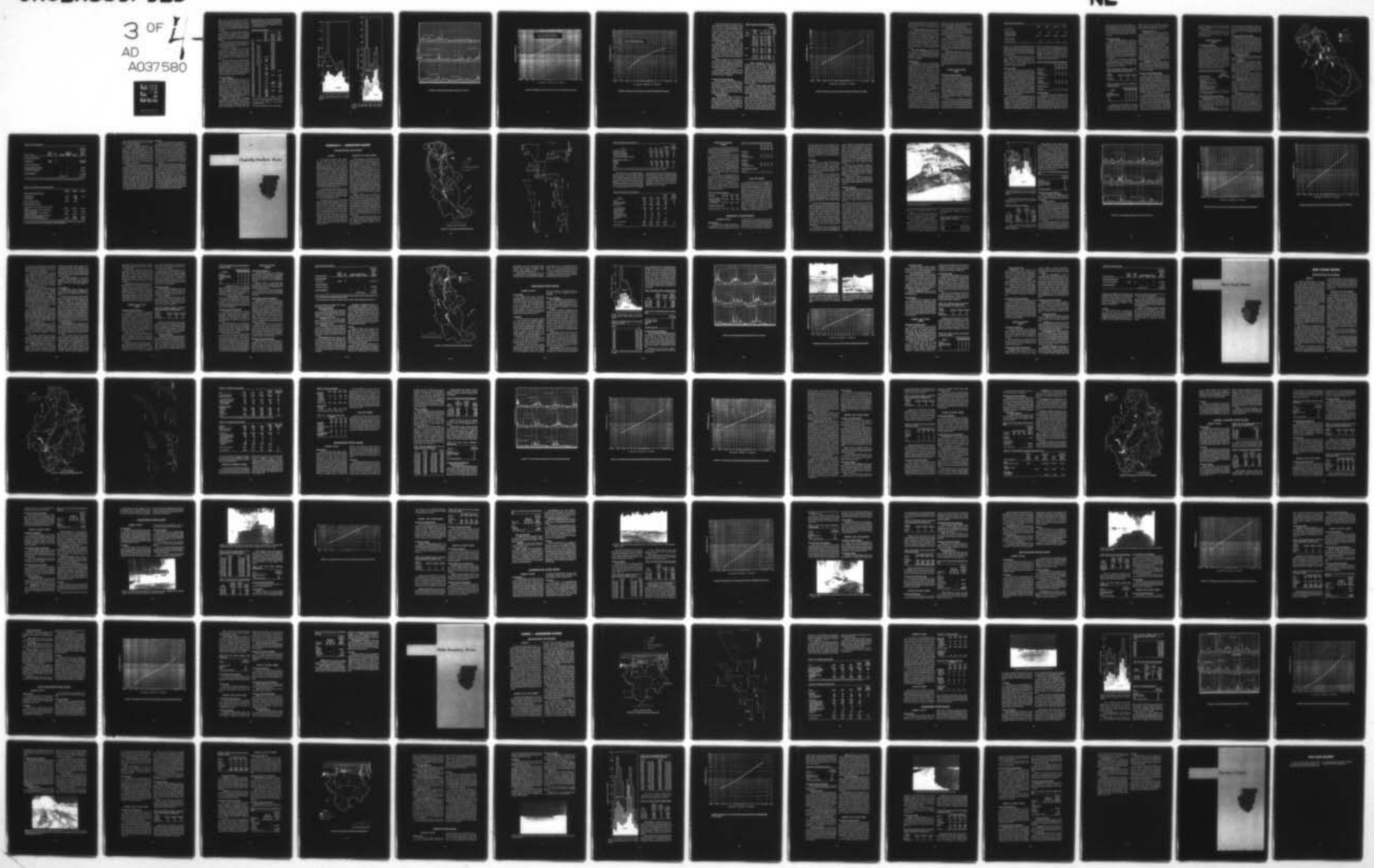
### Flood Plain

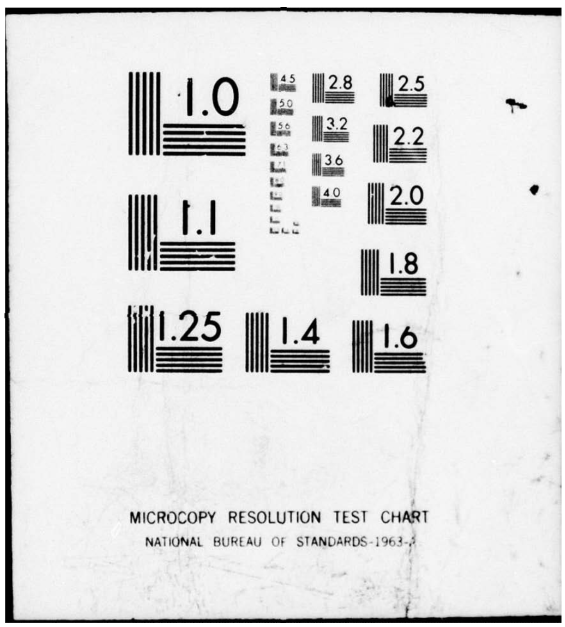
The relatively narrow valleys above Orting on the Puyallup River and Auburn on the White River open onto an 18,500-acre flood plain that varies in

AD-A037 580 PACIFIC NORTHWEST RIVER BASINS COMMISSION VANCOUVER WASH F/G 8/6
COMPREHENSIVE STUDY OF WATER AND RELATED LAND RESOURCES. PUGET --ETC(U)
MAR 70 A T NEALE, S STEINBORN, L F KEHNE

UNCLASSIFIED NL

3 OF 4
AD
A037580




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

width from 1½ miles near Orting to 3/4 mile at Sumner. Below Sumner, the flood plain is 2 to 2½ miles wide. Bedload deposits decrease the capacity of the Puyallup River channel, particularly at the confluence of the Carbon and Puyallup Rivers, and result in inundation and serious erosion of flood plain lands near Orting.

Development in the flood plain includes the industrial section of Tacoma, cultivated agricultural lands and related buildings, fruit and vegetable processing and freezing, and meat packing plants in Orting, Auburn, Pacific City, Sumner, Puyallup and Alderton.

Major transportation facilities include the Great Northern, Northern Pacific, and Chicago, Milwaukee, St. Paul and Pacific Railroads, Interstate Highway 5, and U.S. Highways 99 and 410.

Secondary State highways and county roads provide access to all populated areas. The upper Puyallup and its tributaries are crossed by 12 State and four county highways and four railroad bridges. The city of Tacoma's water pipeline from the Green River watershed crosses the Puyallup River near Auburn.

The Puget Sound Power and Light Company has water rights to divert 2,000 cfs from the White River near Buckley, 5 miles downstream from Mud Mountain Dam. The water is diverted into a series of flumes and canals that extend a distance of 7 miles to Lake Tapps, thence by penstock to the powerplant at Deringer and returned to the river 4 miles upstream from its confluence with the Puyallup River. Lake Tapps has a storage capacity of 46,600 acre-feet.

## History of Flooding

**Flood Characteristics**–High flows on the Puyallup River generally follow the runoff pattern for other rivers in the Puget Sound Area. Major flows coincide with maximum precipitation in the fall or winter, and a secondary peak occurs when rising temperatures melt the accumulated snowpack in the spring or early summer. Figures 9-3 and 9-4 show the runoff patterns for the Puyallup River at Puyallup and the White River near Buckley. Figure 9-5 contains daily discharge hydrographs for the Puyallup River at Puyallup from 1950 through 1958.

**Floods**–The Puyallup River at Puyallup, established in 1914, measures runoff from 98% of the basin and offers the best index of total basin runoff. Table 9-4 lists major discharges at this and other upstream gaging stations from 1906 through 1965. Since 1943, discharges on the White and lower Puyallup Rivers have been controlled by storage in Mud Mountain Reservoir, a Corps of Engineers flood control project on the White River. Figures 9-6 and 9-7 estimate probable annual maximum flows with regulation by this project.

**TABLE 9-4. Major discharges**

| Year | Month | Puyallup River Near Orting (Over 7,000 cfs) | Puyallup River at Puyallup[2] (Over 25,000 cfs) | White River Near Sumner[2] (Over 7,000 cfs) |
|---|---|---|---|---|
| 1906 | | | 36,000[1] | |
| 1909 | | | 27,500[3] | |
| 1917 | 18 Dec. | | 40,500 | |
| 1917 | 30 Dec. | | 30,100 | |
| 1919 | 23 Jan. | | 36,500 | |
| 1921 | 1 Dec. | | 27,000 | |
| 1921 | 13 Dec. | | 35,600 | |
| 1923 | 6 Jan. | | 31,000 | |
| 1927 | 25 Nov. | | 25,400 | |
| 1932 | 26 Feb. | | 33,000 | |
| 1932 | 13 Nov. | 11,800 | 37,800 | |
| 1933 | 8 Jan. | | 25,300 | |
| 1933 | 10 Dec. | 12,800 | 57,000 | |
| 1933 | 21-22 Dec. | 8,480 | 45,700 | |
| 1934 | 23 Jan. | | 28,600 | |
| 1934 | 25 Oct. | | 39,500 | |
| 1934 | 5 Nov. | 8,900 | 30,400 | |
| 1935 | Jan. | | 26,200 | |
| 1938 | Apr. | 8,680 | 33,900 | |
| 1942 | Nov. | 7,450 | 25,700 | |
| 1945 | Dec. | | | 11,400 |
| 1946 | Oct. | 7,040 | | |
| 1946 | Nov. | 7,040 | | |
| 1946 | Dec. | 11,200 | 33,800 | 13,100 |
| 1947 | Oct. | | | 7,950 |
| 1947 | Nov. | 8,300 | | |
| 1949 | May | | | 7,190 |
| 1949 | Nov. | 9,720 | | |
| 1951 | Feb. | | 29,800 | 12,200 |
| 1953 | Dec. | 10,100 | 34,500 | 11,700 |
| 1955 | June | | | 7,380 |
| 1955 | Dec. | 12,100 | 37,600 | 15,100 |
| 1959 | Jan. | | | 11,900 |
| 1959 | Oct. | 8,820 | | |
| 1959 | Nov. | 12,900 | 35,600 | 14,700 |
| 1962 | Nov. | 15,300 | | 7,420 |
| 1963 | Feb. | 10,800 | | |
| 1964 | Dec. | 7,930 | | |
| 1965 | 29 Jan. | 12,200 | 41,500 | 14,100 |

[1] Estimated from gage-discharge relations at Alderton gage.

[2] Includes effect of regulation by Mud Mountain Dam–beginning in 1943.

[3] Estimated from gage-discharge relation at Electron gage.

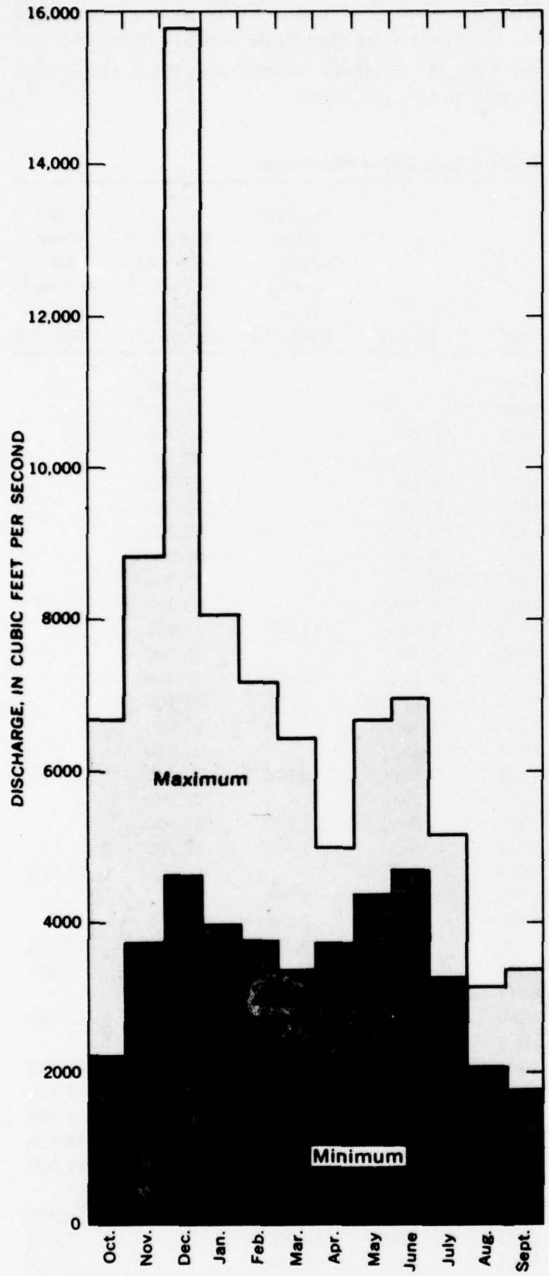



FIGURE 9-3. Maximum, mean and minimum monthly discharges, Puyallup River at Puyallup, 1931-60.

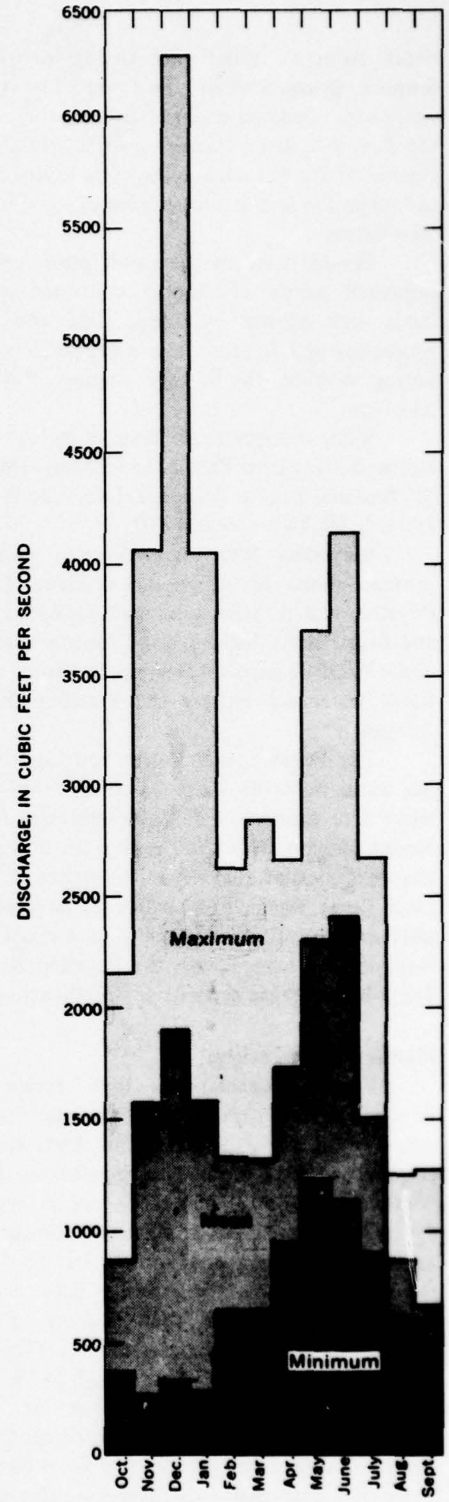



FIGURE 9-4. Maximum, mean and minimum monthly discharges, White River near Buckley, 1931-60.

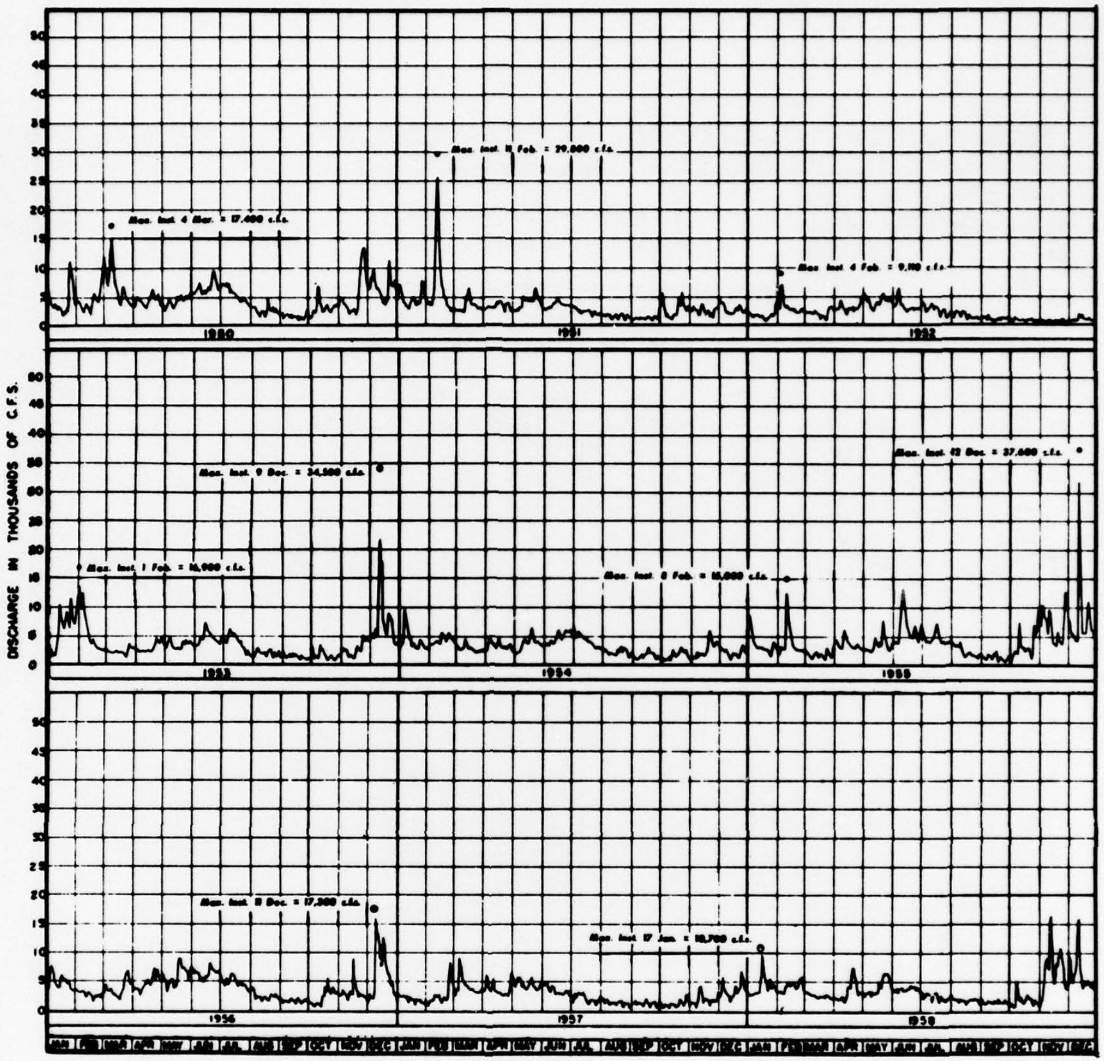



**FIGURE 9-5. Daily discharge hydrograph, Puyallup River at Puyallup.**

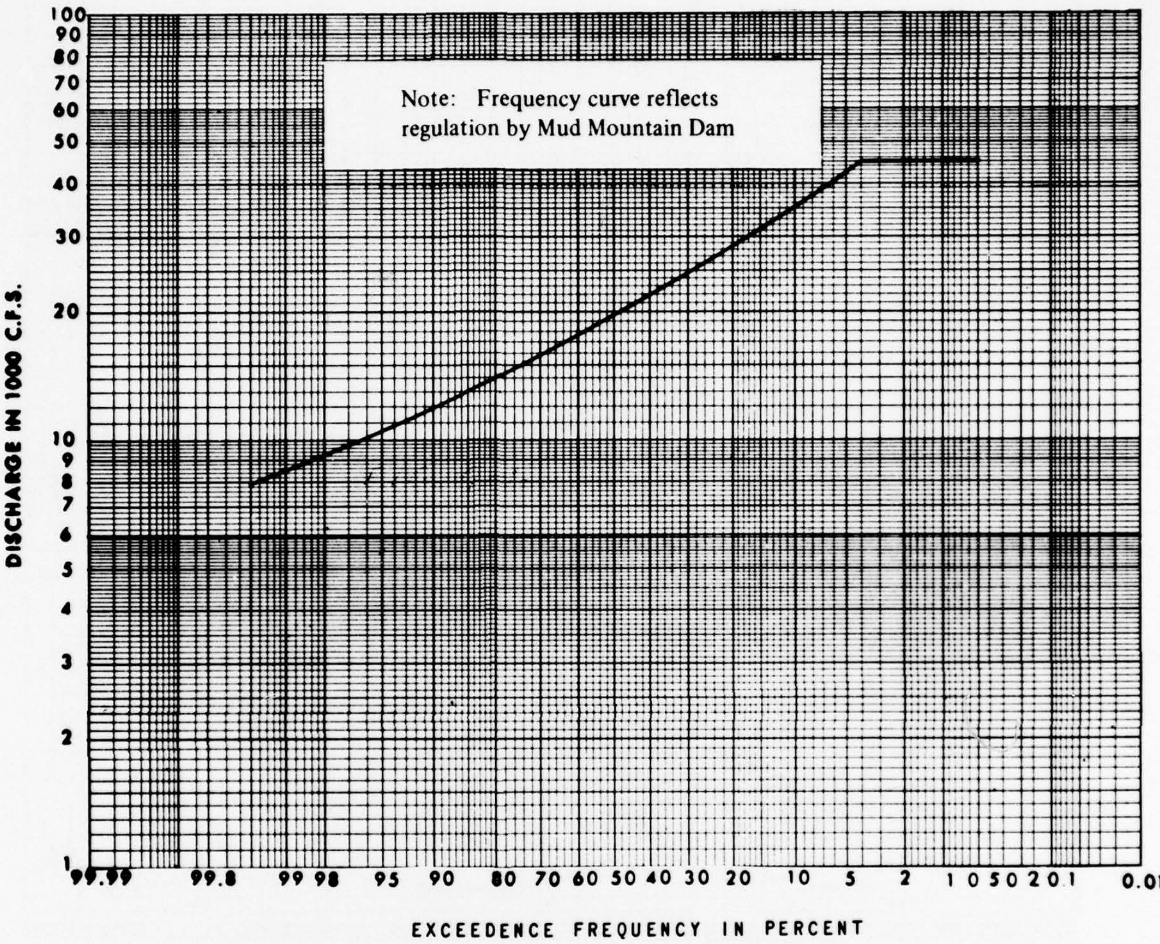



**FIGURE 9-6. Frequency curve of annual maximum peak flows, Puyallup River at Puyallup**

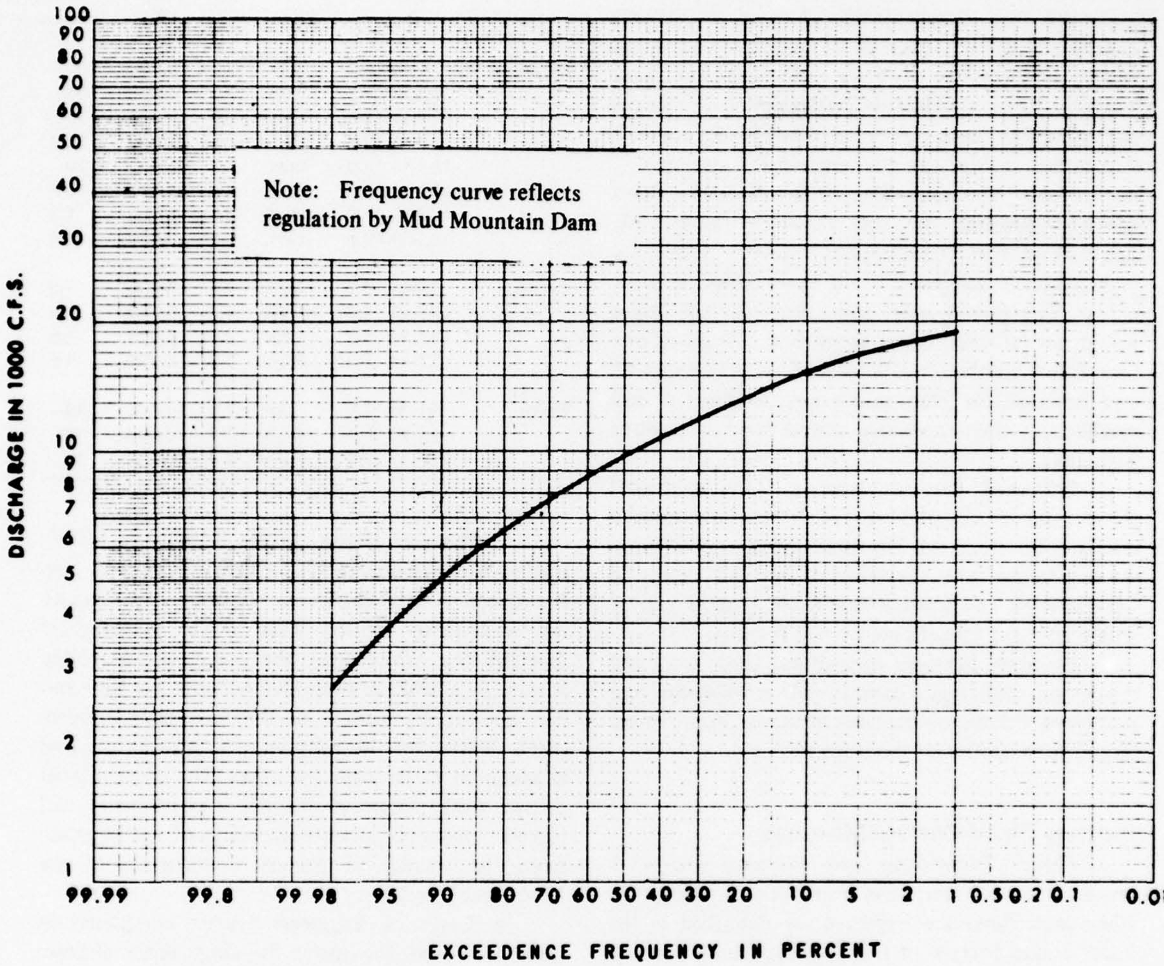



**FIGURE 9-7. Frequency curve of annual maximum peak flows, White River near Sumner**

The most recent flood was on 29 January 1965. The natural peak discharge was estimated to have been 53,000 cfs, but the Mud Mountain project reduced this flow to 41,500 cfs at Puyallup. A flood with a recurrence interval of 100 years can be controlled to within-bank capacities of 20,000 and 45,000 cfs on the lower White and lower Puyallup Rivers, respectively. Above Sumner, the gage Puyallup River at Alderton has recorded discharges intermittently since February 1927. Figure 9-8 estimates probable peak discharges at this station.

**Flood Damages**—The first detailed flood damage appraisal for the Puyallup flood plain downstream from Sumner was made in 1938, and included an investigation of all levees to locate weak points. The investigation concluded that the levees would not fail until the river reached a height of one foot below the top of the levee. The 1938 appraisal was updated to 1966 prices and conditions, and resulted in estimated average annual flood damages of $100,000.

Estimated damages from a 100-year-interval flood total $1,120,000. About 75% of the damage would occur along the Puyallup River upstream from its confluence with the White River, and along the Carbon River and South Prairie Creek. The remainder would be along Clear Creek east of Tacoma.

Flooding damages agricultural land, farm and residential buildings, commercial enterprises, and roadways. Details on damages are given in the Puget Sound Area Section of this appendix.

## Existing Flood Control Measures

**Flood Forecasting and Warning**—The U.S. Weather Bureau alerts the Pierce County Engineer when high flows are expected, as described in the Puget Sound Section of this appendix. Employees of the Inter-County Improvement District and the Pierce County road department also warn the county engineer of conditions conducive to flooding on the Puyallup and its tributaries.

**Flood Protective Works**

**Levees**—Extensive levees have been constructed through the joint efforts of the city of Tacoma, the Inter-County Improvement Commission, the Washington State Department of Highways, and the Federal Government. The levees are below the town of Puyallup and from Sumner to Orting on the Puyallup River, and along the White and Carbon Rivers. Their locations are given in Table 9-5.

**TABLE 9-5. Protection provided by existing levees**

| Location | | | | Protection | |
|---|---|---|---|---|---|
| River | River Mile | Bank | Miles of Levee | To Flow (cfs) | Recurrence Interval (Years) |
| Puyallup | 0.6 to 7.6 | Left | 7.0 | 45,000 | 100 |
| | 0.6 to 9.1 | Right | 8.5 | 45,000 | 100 |
| | 10.9 to 11.4 | Left | 0.5 | 21,000 | 10 |
| | 11.4 to 12.0 | Right | 0.6 | 21,000 | 10 |
| | 13.4 to 12.0 | Left | 1.4 | 21,000 | 10 |
| | 16.5 to 17.6 | Right | 1.0 | 21,000 | 10 |
| | 19.0 to 25.6 | Right | 6.6 | 5,000 | 1.5 |
| | 19.7 to 25.6 | Left | 5.9 | 5,000 | 1.5 |
| Carbon | 0.0 to 4.0 | Left | 4.0 | 6,000 | 1.5 |
| | 0.0 to 1.2 | Right | 1.2 | 6,000 | 1.5 |
| | 4.5 to 8.3 | Left | 3.8 | 6,000 | 1.5 |
| | 5.5 to 7.2 | Right | 1.7 | 6,000 | 1.5 |
| White | 4.0 to 13.0 | Left | 9.0 | 15,000 | 10 |
| | 4.5 to 8.1 | Right | 3.6 | 15,000 | 10 |
| | 22.4 to 22.8 | Right | 0.4 | 15,000 | 10 |

**Channel Improvements**—Prior to 1906, moderate flows on the White River overflowed into the Green near Auburn. In 1906, a high-velocity overbank flow on the White River permanently diverted the White into the Stuck and Puyallup Rivers. As a result of these channel changes, King and Pierce Counties formed an Inter-County Improvement District for the purpose of improving the new channels to carry increased flows. The improvement district made extensive channel improvements, and placed revetments along both banks of the Puyallup from the vicinity of Auburn downstream to the Tacoma city limits.

A Corps of Engineers project completed in 1950 improved the lower Puyallup River channel through Tacoma. The project increased the channel capacity to 45,000 cfs and included channel straightening, levees, revetments and bridge alterations. The lower 3,800-foot-reach is the Puyallup Waterway.

**Bank Protection**—The Corps of Engineers constructed extensive bank protective works along several reaches of the Puyallup River above Sumner, and on the Carbon River and South Prairie Creek in 1936. Much of the original work is no longer effective; however, Pierce County has replaced some of these works in reaches where bank erosion was critical. The county also has provided channel rectification and bank stabilization works along the Carbon

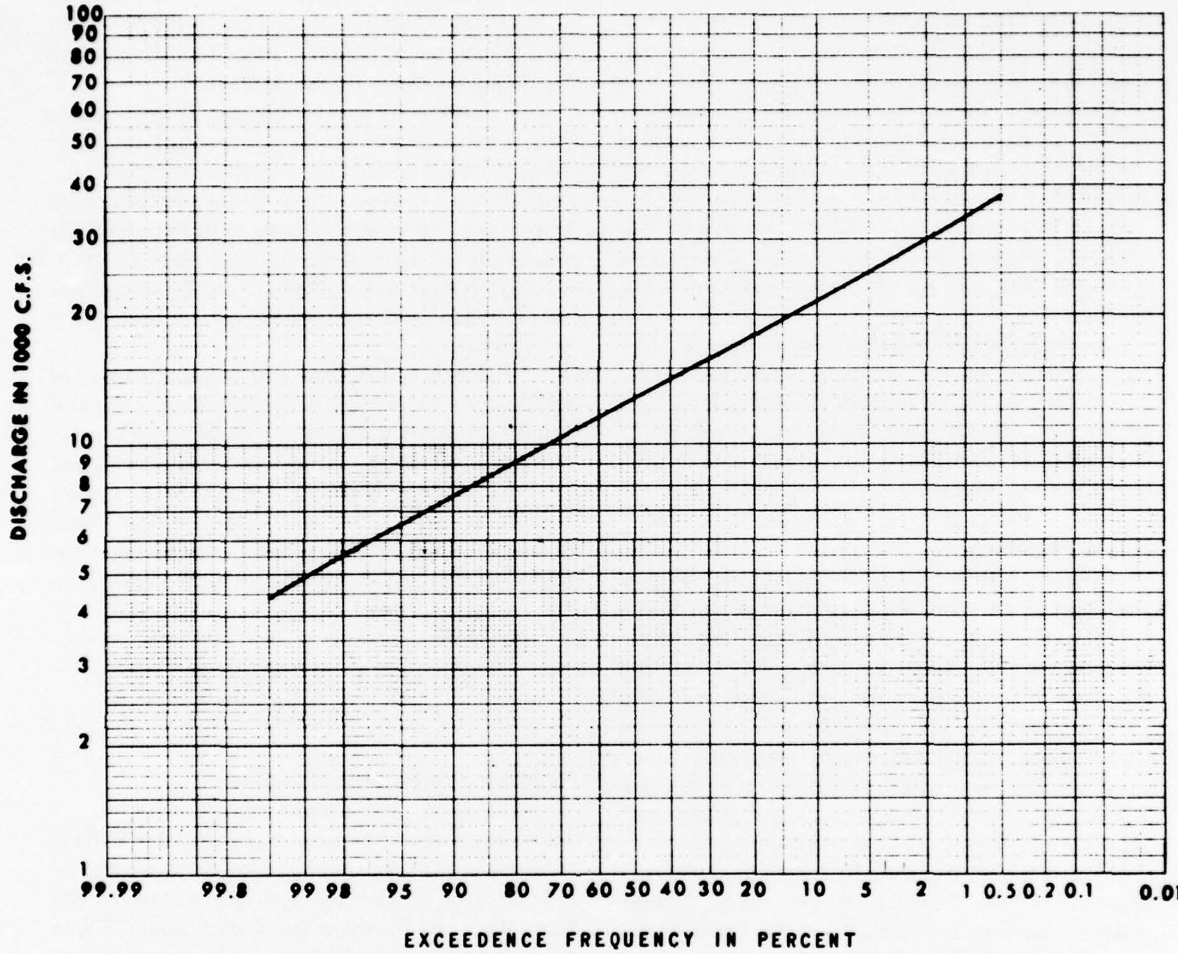



**FIGURE 9-8. Frequency curve of annual maximum peak flows, Puyallup River at Alderton**

and upper Puyallup Rivers. These works appear to be effectively preventing bank erosion, but do not prevent inundation along the upper Puyallup during major floods.

**Flood Control Storage**—Mud Mountain Dam, a Corps of Engineers project on the White River, is approximately 7 road miles upstream from Enumclaw. Operation of the project began in 1943. The reservoir has a storage capacity of 106,000 acre-feet to the crest of an uncontrolled spillway, and is operated exclusively for flood control. No conservation pool is maintained for low flow augmentation. The project regulates floodflows to within safe channel capacities on the White River downstream from the dam and on the lower Puyallup below Sumner.

**Flood Plain Management**—No ordinances have been adopted in the Puyallup Basin to control development in the flood plain. However, flood plain management services are available from the Corps of Engineers, as discussed in the Puget Sound Area Section of this appendix.

### Flood Problems

**Puyallup River**—Flooding is confined largely to the upper flood plain where steep mountain slopes suddenly level off to a relatively flat gradient. Major flooding occurs along the 5-mile reach of the Puyallup upstream from its confluence with the Carbon River. In the lower 4-mile reach of the Carbon River, Orting and vicinity experience minor flooding. Sand and gravel deposited by both rivers reduce the channel capacity of the Puyallup and contribute to overbank flows. Continuous maintenance is required to retain the minimum channel capacity of the Puyallup in this reach. Present channel capacities are estimated to be 5,000 cfs for the Puyallup and 6,000 cfs for the Carbon River.

**Tributary Streams**—Small watersheds not inundated by high flows on the Puyallup River are discussed in the following paragraphs:

Clear Creek and Clark's Creek enter the Puyallup River from the south at approximately river miles 3 and 6, respectively. High water in the river prevents normal drainage and the resulting backwater covers low-lying lands in the flood plain. Alderton Creek enters the Puyallup 2 miles south of Sumner at approximately river mile 13, and is similarly blocked by highwater in the river. As a result of poor drainage, flooding also occurs along Lawrence Creek southeast of Orting, and Fennel and Riverside Creeks southeast of Sumner. These creeks overflow their banks almost annually, damaging crops, farm buildings, roads, bridges and other improvements.

**White River**—Several small tributaries of the White River overflow their banks each year because of inadequate channels, particularly in the populated areas along Salmon Creek near Sumner and the Pacific-Algona region west of Auburn.

**Carbon River**—There is little cultivated land along the Carbon River or its principal tributary, Voight Creek. The land that is cultivated is near or a short distance upstream from Orting. High flows on Voight and Copler Creeks have caused considerable damage in the Carbon River flood plain. In 1965, extensive damage was sustained by the Puyallup River Fish Hatchery and agricultural land upstream from the hatchery.

**South Prairie Creek**—Above the junction of South Prairie Creek and the Carbon River, cultivated farm land borders the creek for about 4 miles in the vicinity of the village of South Prairie. The creek and its principal tributary, Wilkeson Creek, have a history of high velocity flows and severe erosion. After extensive damage in 1965, the Corps of Engineers placed riprap along the creek's banks to protect farm land.

## PRESENT AND FUTURE NEEDS

### Evaluation of Present Situation

The flood plain downstream from Auburn on the White River and Sumner on the Puyallup River is protected from floods with a recurrence interval of 100 years or greater by upstream storage on the White River and by levees and channelization. Within the protected area are 850 acres of land on the White River and 6,150 acres below Sumner on the Puyallup River, including the towns of Pacific, Algona, Sumner, Puyallup, and Fife, and the industrial area of Tacoma. The flood plain outside these communities is occupied by cultivated farm land with related buildings and developments, residences, and commercial developments.

Above Sumner, the 10,500-acre flood plain contains numerous homes in Sumner and vicinity and cultivated farm land between Alderton and Orting. Levees provide protection against flood flows with a recurrence interval of over 10 years below Orting, but Orting and vicinity are flooded frequently. The steep

TABLE 9-6. Economic projections

| | 1963 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Central Division | | | | |
| Population (millions) | 1.6 | 2.4 | 3.9 | 6.2 |
| Employment (millions) | 0.6 | 0.8 | 1.4 | 2.2 |
| Gross Regional Product (1963 $ in millions) | $5,172.0 | $10,022.0 | $24,569.0 | $62,061.0 |
| Puyallup River Basin | | | | |
| Population (millions) | 0.3 | 0.4 | 0.7 | 1.2 |

gradients of the Carbon and Puyallup Rivers above Orting cause high velocities that erode the streambanks during high flows. Debris and bedload deposited near the confluence of the Carbon and Puyallup Rivers contribute to overbank flows, channel changes, and further erosion.

On small tributary streams, the lack of adequate channels and drainage facilities results in frequent damage to adjacent improvements. The problem is acute near the mouths of the streams when high stages on the Puyallup prevent the tributaries from discharging properly.

## Economic Trends

The economy of the Puyallup River Basin is closely tied to the economic environment of neighboring counties and the Seattle-Tacoma metropolitan area. The pattern of economic growth for the Central Division comprising the counties of Snohomish, King, Pierce, and Kitsap is representative of the economic conditions in the basin. Projections of economic growth for the Central Division have been made for the years 1980, 2000 and 2020 in Appendix IV. Table 9-6 contains a forecast of population, employment and gross regional product for the Central Division and projects population for the Puyallup River Basin. Table 9-7 converts these forecasts into rates of growth and compares these rates to those projected for the United States.

The Central Division of the Puget Sound Area is forecast to grow at an accelerated rate to the year 2000. In the 57-year period following 1963 the projected average annual growth is 2.4 percent for population, 2.4 percent for employment and 4.4 percent for gross regional product. The pattern of expansion is emphasized when compared to the United States which is expected to realize rates of 1.3 percent, 1.5 percent and 4.0 percent for the same indicators and time periods. The Puyallup River Basin is an integral part of the Seattle-Tacoma urban complex and is directly affected by the current expansion. The population is estimated to rise from 324,500 in 1963, to 1,157,700 in 2020, with employment and gross regional product expected to keep pace with the population growth.

TABLE 9-7. Average annual growth trends (percent)

| | 1963 To 1980 | 1980 To 2000 | 2000 To 2020 | 1963 To 2020 |
|---|---|---|---|---|
| United States | | | | |
| Population | 1.3 | 1.3 | 1.3 | 1.3 |
| Employment | 1.6 | 1.4 | 1.3 | 1.5 |
| Gross National Product | 4.3 | 3.9 | 4.0 | 4.0 |
| Central Division | | | | |
| Population | 2.4 | 2.4 | 2.4 | 2.4 |
| Employment | 2.4 | 2.4 | 2.4 | 2.4 |
| Gross Regional Product | 3.9 | 4.6 | 4.7 | 4.4 |
| Puyallup River Basin | | | | |
| Population | 1.9 | 2.4 | 2.4 | 2.3 |

## Land Use Trends

At the present time intensive land uses occupy some 97,000 acres or 12.8 percent of the Basin's land area. Nearly all of the intensive land use areas are located within or near the Basin's incorporated and unincorporated communities. Present trends show that the Puyallup River valley is destined to develop intensively from the mouth of the river to the city of Puyallup and that there is a good possibility that the fertile agricultural lands between the cities of

Puyallup and Orting may develop intensively. A total of 200,000 acres of land would be required for intensive development by the year 2020. An aggressive flood plain regulation program may be necessary if it is determined desirable to maintain agricultural use of the flood plain lands upstream of the town of Sumner.

## Flood Control Needs

**Prevention of Flood Damages**–The community of Orting has an immediate need for flood control measures as it suffers frequent flood damages. Average annual damages in the basin are estimated at $100,000 at 1966 prices and conditions with the majority of the damages occurring in and adjacent to Orting. These flood damages should be reduced by providing flood protection. The entire flood plain must be zoned to insure that future development of these lands is orderly and consistent with the protection provided.

Based on the methodology and considerations previously discussed for the Puget Sound Area, anticipated flood damages in the flood plains of the Puyallup Basin are expected to increase by the percentages as shown in Table 9-8.

**TABLE 9-8. Percentage increase in productivity levels and developments for specified periods**

| Category of Damage | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Agriculture | 29 | 31 | 31 |
| Non-Agriculture | 55 | 110 | 110 |

**TABLE 9-9. Existing and future annual damages (in thousands of dollars)**

| Category | Under Development Levels of 1966 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Agriculture | 20 | 26 | 34 | 44 |
| Buildings & Equipment | 35 | 55 | 117 | 244 |
| Transportation Facilities | 35 | 54 | 117 | 244 |
| Other | 10 | 16 | 33 | 70 |
| Total | 100 | 151 | 301 | 602 |

Application of these percentages to the average annual damages based on 1966 prices and conditions provides an indication of future damages at 1966 prices if additional flood protection is not provided. Table 9-9 shows that the combination of all categories of damage are expected to increase from about $100,000 in 1966 to $602,000 by the year 2020.

### Optimum Flood Plain Use

**Agriculture**–Farm land is being converted to residential and commercial use as a result of the expansion of the adjacent metropolitan area. Increased population will require additional food needs which can be partially supplied by the rich farm lands located in the Puyallup River flood plain. When feasible, protection against at least 25-year frequency floods should be provided for agricultural lands.

**Intensive Land Use**–Urban and residential development in the Puyallup River Basin is largely affected by expansion of the Seattle-Tacoma metropolitan area, and at the present time this expansion is encroaching upon the flood prone lands in the basin. The use of the flood plain for urban and residential developments in the Puyallup River flood plain above Sumner should not be permitted until 100-year flood protection is provided.

**Recreation**–Portions of the flood plain are expected to be used for parks, golf courses and other general recreation uses. In order to permit construction of park facilities such as restrooms and planting of trees and other greens, a level of flood protection of 10-15 years is required.

## Summary of Flood Control Needs

There is a need to reduce the present average annual flood damages of $100,000 that occur to croplands, buildings, roads and utilities in the flood plain, particularly along the Puyallup River upstream of the town of Sumner. The trend of development within the basin is expected to result in future growth of flood damages approximating 3-3/4 percent compounded annually if additional flood control is not provided. Future growth of average annual flood damages are expected to grow to $151,000 in 1980, $301,000 in 2000, and $602,000 in 2020.

The community of Orting suffers frequent flood damages and should be provided with protection against floods which have a recurrence interval of 100 years or greater. Additional flood control is desirable to protect the increasingly valuable agricultural investment and provide for urban and industrial expansion. On the upper reaches of the Puyallup River and tributaries, particularly South Prairie Creek, loss of land through erosion during flood discharges should be prevented. The entire flood plain

should be managed to permit only those developments that are consistent with the degree of flood protection provided.

Some small tributaries require some flood protective works such as channel improvements and flood gates to allow these streams to properly discharge flood flows.

## MEANS TO SATISFY NEEDS

### Flood Control Objectives

The flood control objectives are to meet the needs set forth in the preceding section by providing flood control through utilization of both structural and nonstructural measures. Objectives of structural measures, shown in Table 9-10, are adequate for intensive development of the entire flood plain. If flood plain regulation and zoning of the Puyallup River flood plain above Sumner for agricultural use is determined to be desirable and is effective, a lower degree of flood protection would be adequate. Nonstructural measures would include a flood plain warning system and flood plain management consistent with the flood protection provided.

**TABLE 9-10. Objectives of structural measures**

| Flood Plain Designation | Levels of Protection[1] 100 Year | 25 Year |
|---|---|---|
| 6,150 acres along Puyallup River below Sumner | X | |
| 10,500 acres along Puyallup River from Sumner to about two miles above Orting | X | |
| 1,000 acres along South Prairie Creek near the town of South Prairie | | X |
| 850 acres along the White River | X | |

[1] For floods that can be expected to occur on an average of once in the period designated.

### Opportunities for Structural Measures

**Upstream Storage**–Potential storage sites exist on the Puyallup River, South Prairie Creek, Carbon River, and Voight Creek. Approximately 55,000 acre-feet of flood control storage would be required on the upper Puyallup and Carbon Rivers to give the required flood protection.

**Levees and Channelization**–Flood control by levee construction would be effective for protection of the urban area of Orting and vicinity and also for the area downstream to Sumner. Channelization improves the flood carrying capacity of the channel and would be effective in the Puyallup River above Sumner.

### Solutions to Flood Control Needs

**General**–Features of the flood control plan are detailed in Table 9-11 and shown on Figure 9-9. Levees, channel improvements and upstream storage are the nucleus of this plan. Flood plain management is an essential part of the flood control plan. The flood control plan would provide for optimum development through the year 2020. Features of this plan are described as single-purpose flood control. Economic justification may depend on consideration of other water resource needs.

**Sequence of Development**

**To 1980**–Flood plain zoning and regulation should be implemented to insure that future flood damages are minimized.

**1980-2000**–Levees and channel improvements for protection of Orting and vicinity should be constructed as soon as possible as this area suffers frequent flood damage. These improvements in combination with flood control storage on the upper Puyallup River would provide the flood plain above Sumner with 100-year protection.

Channel and levee construction for protection in the vicinity of the town of South Prairie along South Prairie Creek should be constructed in this period. Flood plain regulation should be continued.

**2000-2020**–Additional protection for the flood plain from Sumner upstream to Orting could be justified in this period as land use demands are estimated to convert all of these flood plain lands into urban and residential use. This additional protection could be provided by flood control storage on South Prairie Creek. Flood plain regulation should be continued.

**Accomplishments**–Accomplishments of the flood control plan are shown in Table 9-12 and on Figure 9-9. Levees and channelization constructed in the vicinity of Orting and flood control storage on the upper Puyallup River would provide 100-year or greater protection along the Puyallup River from Sumner to Orting in the period 1980-2000. Levees and channelization along South Prairie Creek would provide 25-year protection for this recreational oriented area in the period 1980-2000. Flood control storage on South Prairie Creek would increase protec-

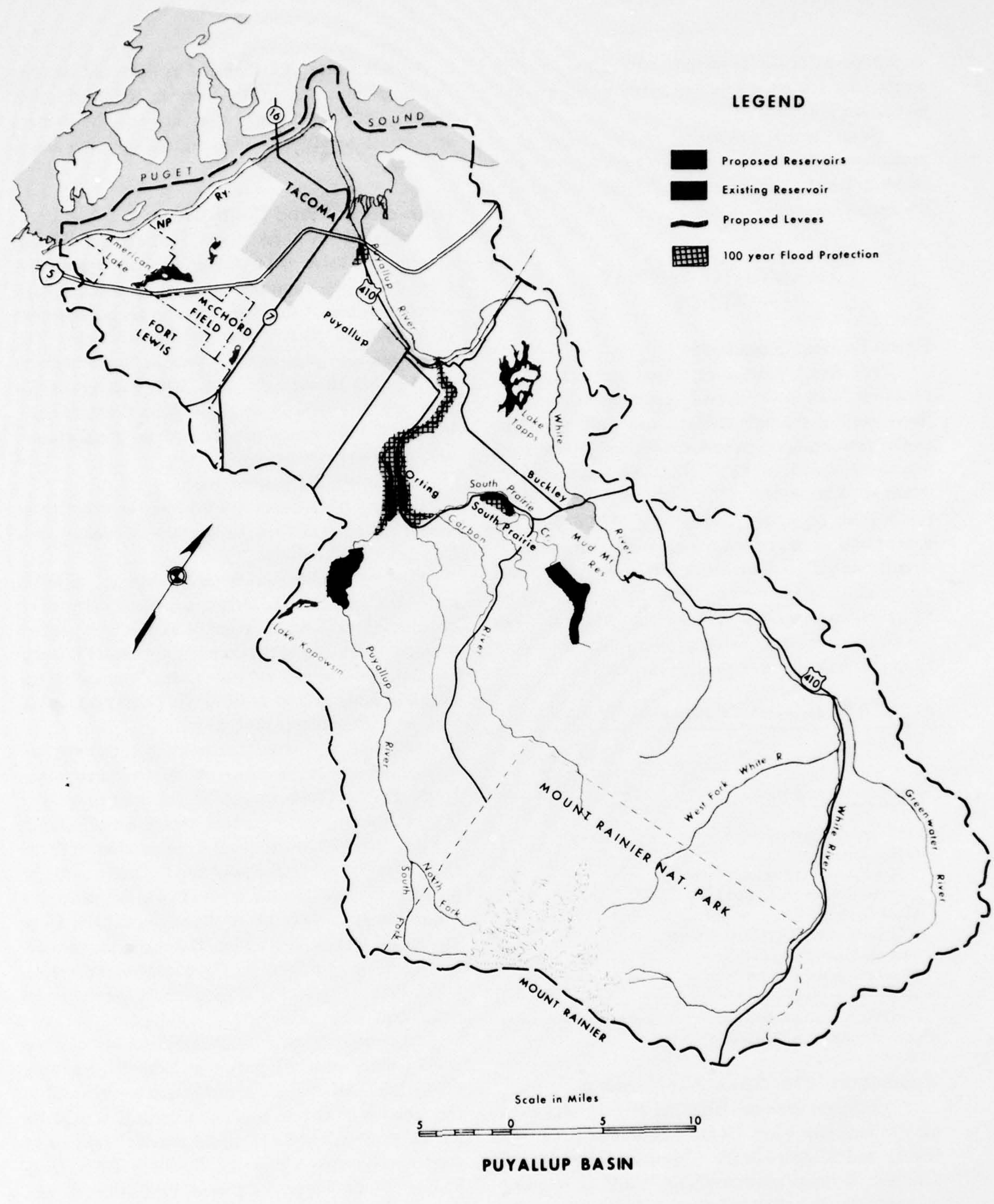



**FIGURE 9–9 Proposed flood control plan and accomplishments**

TABLE 9-11. Flood control plan

| Flood Control Feature | Effective Storage Acre-Feet | River Mile | Sequence of Development To 1980 | To 2000 | To 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|---|---|
| Flood Control Storage Projects | | | | | | |
| Puyallup River | 24,000 | 27 | | X | | $26,500,000 |
| South Prairie Creek | 8,500 | 10 | | | X | 15,300,000 |
| *Channel and Levee Construction* | | | | | | |
| Puyallup and Carbon Rivers at Orting | | | | X | | 1,600,000 |
| South Prairie Creek in the vicinity of the town of South Prairie | | | | X | | 1,000,000 |
| Flood Plain Management | | | X | X | X | 160,000[1] |
| | | | Total Cost of Plan | | | $44,560,000 |

[1] Includes estimated cost of a Flood Plain Information Study and flood plain zoning and regulation implementation costs.

TABLE 9-12. Accomplishments of flood control plan

| | To 1980 | To 2000 | To 2020 |
|---|---|---|---|
| Acreage Protected by Flood Control Plan | | | |
| 100 year protection | 7,000[1] | 16,500 | 18,500 |
| 25 year protection | -- | 1,000 | -- |
| Less than 25 year | 11,500 | 1,000 | -- |
| Flood Plain Management (Acres) | 11,500 | 2,000 | -- |
| Flood Damage Prevention (Dollars) | | | |
| Projected average annual flood damages without additional protection | $151,000 | $301,000 | $602,000 |
| Reduction in future average annual flood damages due to flood plain management | 10,000 | 41,000 | 105,000 |
| Projected residual average annual flood damages with flood plain management | 141,000 | 260,000 | 497,000 |
| Reduction in future average annual flood damages with implementation of structural measures | 0 | 234,000 | 477,000 |
| Projected residual average annual flood damages | 141,000 | 26,000 | 20,000 |

[1] Includes 6,150 acres below Sumner of the Puyallup River flood plain and 850 acres of the White River flood plain presently provided 100 year protection by Mud Mountain Dam and by levees and channelization.

tion to the flood plain from Sumner to Orting and provide 100-year protection to the town of South Prairie in the period 2000-2020.

**Alternatives Considered**—Single-purpose upstream flood control storage projects were determined to be economically infeasible prior to 1980. Multi-purpose storage projects with flood control included as a project purpose may be feasible during this period. Levees and channelization of the Puyallup River from above Orting downstream to Sumner were studied and determined to be economically infeasible. Other measures considered and found not feasible are raising of roads and bridges and evacuation of the flood plain.

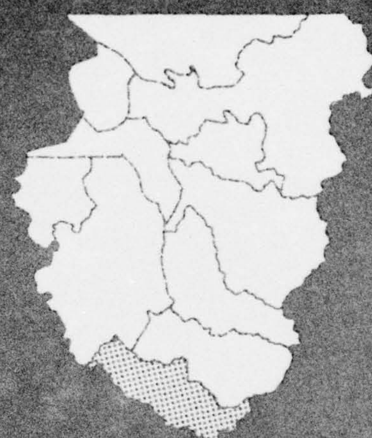
Floodproofing of existing buildings was evaluated as an alternative to major flood protective works for reduction of present and future flood damages. Extensive existing developments in the communities of Sumner, Orting, and South Prairie as well as numerous residences and associated buildings located in rural areas of the flood plain would require floodproofing. Approximately 30 percent of the estimated \$100,000 average annual flood damages occurs to buildings. A high percentage of these buildings are of wood frame construction and floodproofing would require structural treatment that is economically infeasible. This alternative would not meet the present needs for optimum development and utilization of the Puyallup Basin flood plain.

## Summary

The flood plain downstream from Auburn on the White River and Sumner on the Puyallup River is protected from floods with a recurrence interval of 200 years or greater by upstream storage at Mud Mountain Dam and by levees and channelization. Above Sumner the 10,500-acre flood plain contains numerous homes in Sumner and Orting and cultivated farm land. Levees provide protection against flood flows with a recurrence interval of approximately 10 years below Orting, but Orting and vicinity are flooded frequently. Average annual flood damages are estimated to be \$100,000 based on 1966 prices and conditions.

Studies indicate that future flood damages may be expected to increase in proportion to the increase in economic activity in the flood plain if additional protection is not provided. The trend of development within the basin would result in future growth of flood damages approximating 3-3/4 percent compounded annually without flood control and will result in future growth of annual damages to \$151,000 in 1980, \$301,000 in 2000, and \$602,000 in 2020. These existing and projected damages should be reduced by providing additional flood protection to allow development of the full economic potential of the basin. Implementation of the flood control plan would significantly reduce flood damages and permit increased utilization of the flood plain.

# Nisqually-Deschutes Basins



# NISQUALLY — DESCHUTES BASINS

## DESCRIPTION OF BASINS

### GENERAL

The Nisqually and Deschutes Basins, Figure 10-1, cover about 1,044 square miles in Pierce, Thurston, and Lewis Counties. The basins are bounded on the north by Puget Sound and the Puyallup River drainage, on the east by Mount Rainier National Park, and on the south and west by the Cowlitz and Chehalis River drainages. The eastern portion of the basin is rugged and irregular and reaches an elevation of 14,408 feet at the summit of Mount Rainier. Most of the basin is heavily forested. From the town of LaGrande west to Puget Sound, the basin is generally below elevation 1,000 feet and characterized by rolling, forested foothills broken by occasional gravelly prairies and shallow lakes. The area is drained by the Nisqually and Deschutes Rivers, which discharge into Puget Sound. Streambed profiles of these rivers are shown on Figure 10-2.

Gently sloping moraines, several large lakes and numerous bogs of clay and peat occupy the wide plain between the Nisqually and Deschutes Rivers. Sand, gravel and glacial till are widespread, and the thin, dry soil is generally poor, except for the fertile, silty loam in the Nisqually River delta.

In common with most of the Puget Sound Area, the Nisqually-Deschutes Basin has a mild, wet climate. Average annual precipitation ranges from about 40 inches in the vicinity of LaGrande to more than 100 inches on the slopes of Mount Rainier. About 75 to 80 percent falls during the period October through March, with much of the precipitation at the higher elevations in the form of snow. Mean annual snowfall varies from 16 inches at Olympia to 582 inches at the Paradise ranger station on Mount Rainier. During the winter, temperatures usually are from 40°F to 50°F during the day and drop into the 30's at night. Temperatures during the summer range from about a minimum of 70°F to a maximum of 80°F.

### ECONOMY–PAST AND PRESENT

Current population of these Basins totaled over 67,000 in 1967. Annual growth rate has averaged 1.7 percent during the past 27 years as compared to an annual growth rate of 2.7 for the entire Puget Sound Area. Olympia, the State Capitol, is located in the delta area of the Deschutes Basin. This city is important not only in its role as State Capitol but as the principal port serving south Puget Sound. The Port of Olympia comprises over 72 acres mostly surrounding Budd Inlet. It is equipped to handle any cargo from both ocean vessels and local water freight. Industries, primarily forest products, building products and cold storage plants, occupy much of this property. The West Bay terminal presently serves as an export log receiving, handling and rafting site. Beyond Budd Inlet, Olympia Harbor accommodates a reserve fleet of over 100 merchant ships of the United States Maritime Administration. Population trends for the Deschutes and Nisqually Basins, their environment and cities and towns within the Basin are shown on Table 10-1.

Logging, lumbering, and the production of forest products, have always been the Basin's economic mainstay; while mining, farming and fishing, also, were early industries that helped shape the future. Today, other commodities such as metal craft, can manufacturing, boat building, cold storage, and meat packing are of marked importance and give the area a diversified commercial base. Olympia Brewing Company is located in the town of Tumwater. Fort Lewis, a large Army training facility, is located partly within the Nisqually-Deschutes Basin and is an important factor in the economy of the basin and adjacent areas.

Localized farming districts within the basins are intensively managed. The raising of livestock is the most important agricultural enterprise; however, berry growing and poultry production also are important activities.

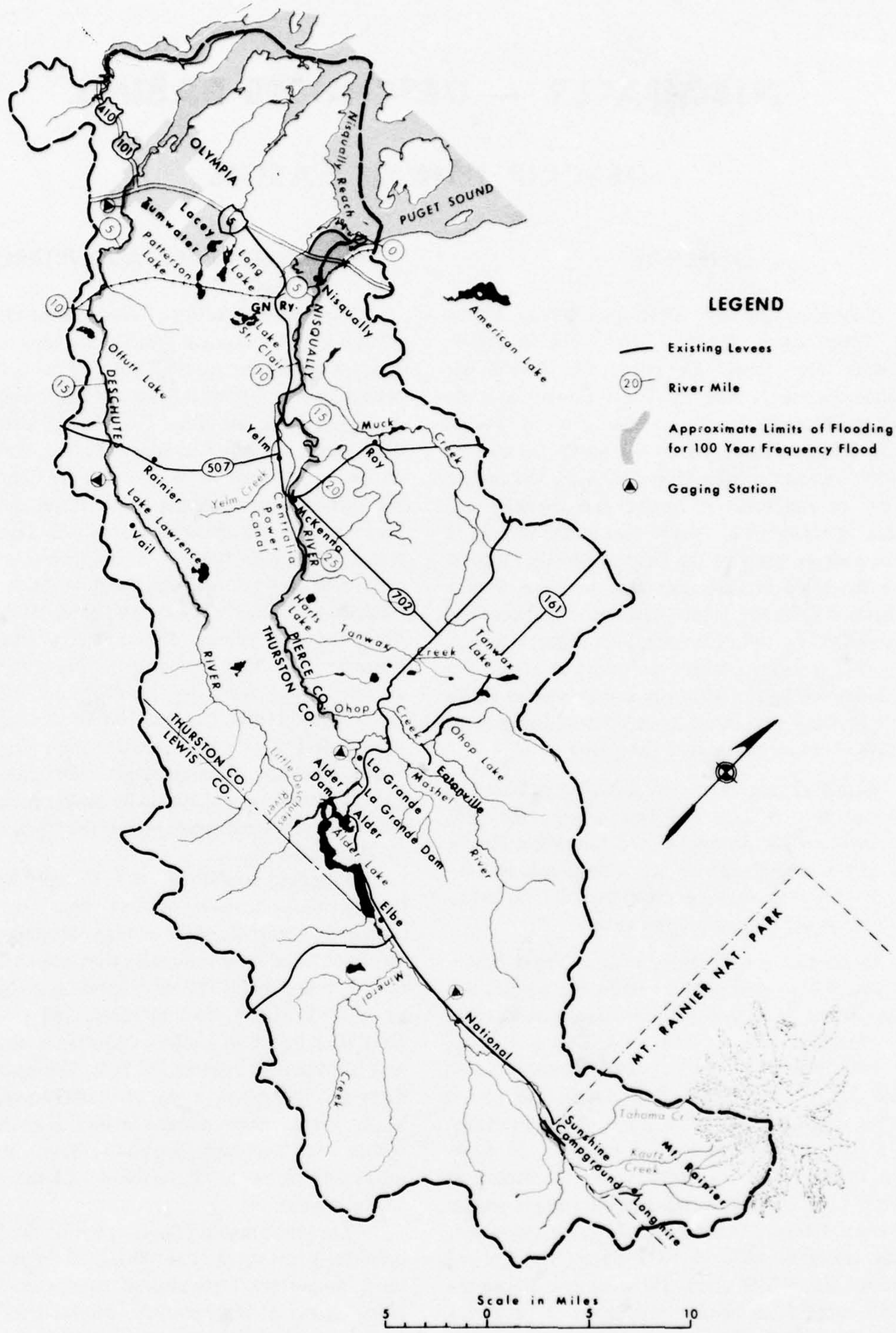
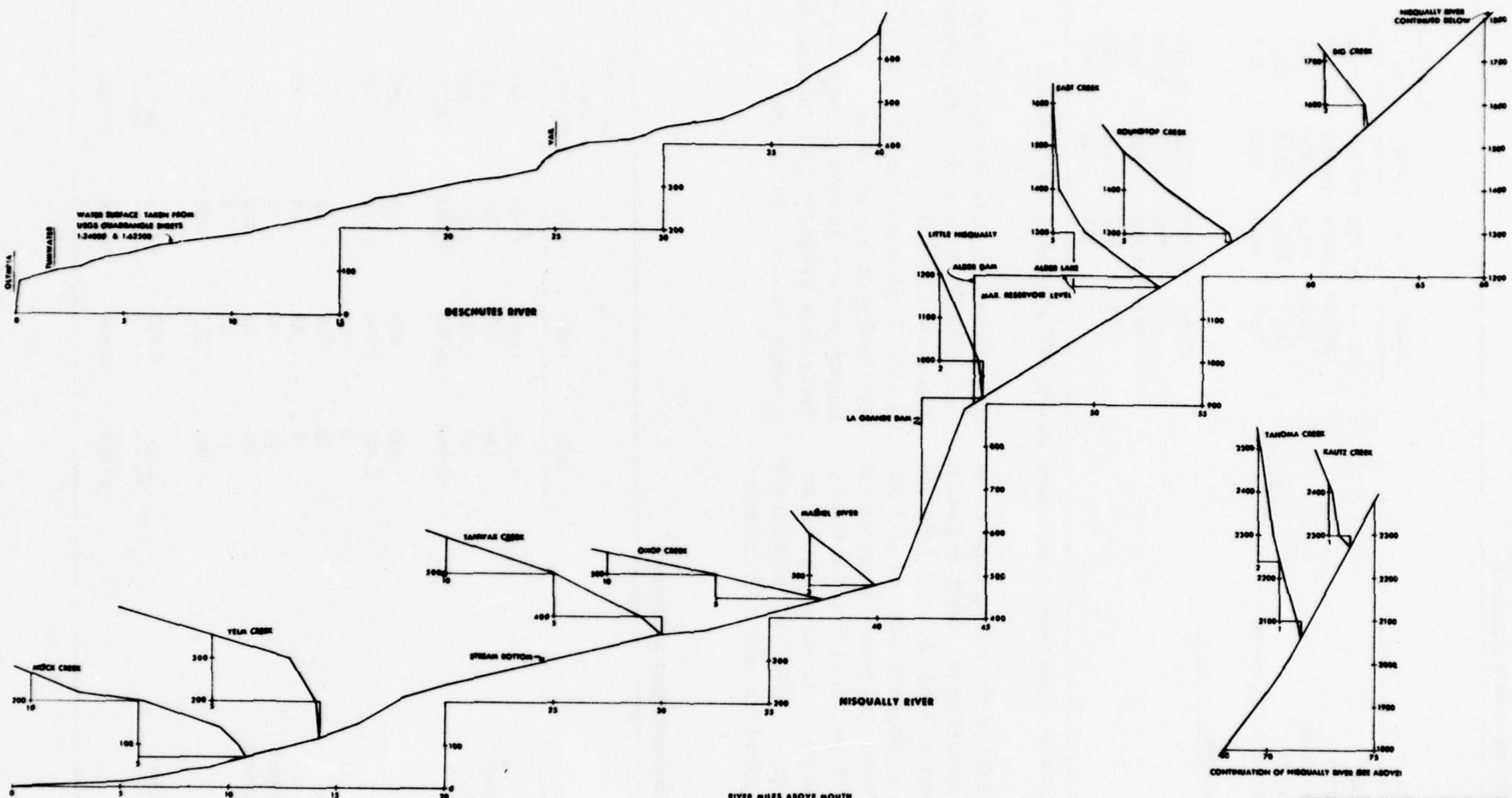



FIGURE 10-1. Flood plain and existing protective works




NISQUALLY RIVER & DESCHUTES RIVER PROFILES

FIGURE 10-2

**TABLE 10-1. Population– past and present**

| Area | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| United States (thousands) | 132,164 | 151,326 | 179,323 | 200,100 | 52 |
| Puget Sound (thousands) | 1,007.0 | 1,418.4 | 1,768.0 | 2,100 | 105 |
| Thurston County (thousands) | 37.3 | 44.9 | 55.0 | 64.6 | 73 |
| Pierce County (thousands) | 182.1 | 275.9 | 321.6 | 378.3 | 108 |
| Nisqually & Deschutes Basins (thousands) | 39.6 | 48.6 | 59.3 | 70.1 | 77 |
| Cities and Towns in the Basin | | | | | |
| Olympia | 13,254 | 15,819 | 18,273 | 20,880 | 58 |
| Tumwater | 955 | 2,725 | 3,885 | 4,698 | 392 |
| Eatonville | 996 | 1,048 | 896 | 900 | -- |
| Yelm | 378 | 470 | 479 | 525 | 40 |
| Rainier | -- | 331 | 245 | 311 | -- |

Figures are from U.S. Census Report, Seattle Area Industrial Council, 1967, and Appendix IV, Economics.

State Government is the leading employer in Thurston County, accounting for almost 36 percent of total employment in 1963. Between 1950 and 1960, Government employment increased 28.7 percent in the United States, 13.1 percent in the State of Washington, and 47.0 percent in Thurston County. Manufacturing employment increased only 8.0 percent in the 27-year period, 1940-1967. Employment in food processing gained the most in the manufacturing sector since 1940. Principal items processed are dairy products, beer, poultry, and Olympia oysters. This sector increased from 400 in 1940 to over 1,000 in 1967. Employment trends for 1940 through 1967 for Thurston County are shown in Table 10-2 below. Employment for Thurston County was selected to demonstrate trends for the basin since data for the complete basin was not available.

***TABLE 10-2. Employment—past and present***

| Industry | 1940 | 1950 | 1960 | Estimated 1967 Employ | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| Agriculture | 1,635 | 1,483 | 1,113 | 990 | -39 |
| Forestry, Fishing, Mining | 134 | 175 | 202 | 220 | 64 |
| Contract Construction | 727 | 1,352 | 1,657 | 920 | 27 |
| Manufacturing | (3,453) | (3,390) | (3,483) | (3,720) | 8 |
| Food & Kindred Prod. | 409 | 560 | 750 | 1,030 | -- |
| Lumber, Wood & Furn. | 2,745 | 2,354 | 2,070 | 1,840 | -- |
| Paper & Allied Prod. | 3 | -- | -- | -- | -- |
| Chem. & Allied Prod. | 20 | 55 | 62 | -- | -- |
| Fabricated Metal | 5 | 78 | 54 | 200 | -- |
| Mach. (Elec. & Non-Elec.) | 40 | 50 | 65 | -- | -- |
| Transportation Equipment | 25 | 20 | 139 | -- | -- |
| Primary Metal | 17 | 11 | 8 | 0 | -- |
| Other | 189 | 262 | 335 | 650 | -- |
| *Non-Commodity Industry* | 6,859 | 9,490 | 13,023 | 19,150 | 179 |
| Total Employment | 12,808 | 15,890 | 19,478 | 25,000 | 95 |

## PROJECTED ECONOMIC TRENDS

The economy of the Nisqually River Basin is influenced by the metropolitan areas of Olympia and Tacoma, by the Fort Lewis Military Reservation, and by forestry and recreational enterprises.

The pattern of economic growth for the basin in the past has been slower than that of the entire Puget Sound Area and this trend is expected to continue in the future. Projections of economic growth for the West Division have been made for the years 1980, 2000, and 2020 in Appendix IV. Table 10-3 contains a forecast of population, employment, and gross regional product for the West Division and projected population for the Nisqually River Basin. Table 10-4 converts these forecasts into rates of growth and compares these rates to those projected for the United States.

The West Division of the Puget Sound Area is forecast to grow somewhat less rapidly than the other divisions. In the 57-year period following 1963, the projected average annual growth is 1.2 percent for population, 1.3 percent for employment, and 2.7 percent for gross regional product. The major growth strength in the Nisqually Basin is drawn from the forest products industry and from increasing tourism and summer home growth.

**TABLE 10-3. Economic projections**

| West Division | 1963 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Population (thousands) | 116.0 | 122.5 | 169.5 | 232.4 |
| Employment (thousands) | 37.7 | 41.9 | 57.6 | 79.5 |
| Gross Regional Product (millions 1963 $) | 290.0 | 498.0 | 1,066.0 | 1,329.0 |
| **Nisqually-Deschutes River Basin** | | | | |
| Population (thousands) | 69.6 | 74.9 | 104.5 | 146.5 |

**TABLE 10-4. Average annual growth trends (percent)**

| | 1963 To 1980 | 1980 To 2000 | 2000 To 2020 | 1963 To 2020 |
|---|---|---|---|---|
| **United States** | | | | |
| Population | 1.3 | 1.3 | 1.3 | 1.3 |
| Employment | 1.6 | 1.4 | 1.3 | 1.5 |
| Gross National Product | 4.3 | 3.9 | 4.0 | 4.0 |
| **West Division** | | | | |
| Population | 0.3 | 1.7 | 1.6 | 1.2 |
| Employment | 0.6 | 1.6 | 1.6 | 1.3 |
| Gross Regional Product | 3.2 | 3.9 | 1.1 | 2.7 |
| **Nisqually-Deschutes River Basin** | | | | |
| Population | 0.4 | 1.7 | 1.7 | 1.3 |

## LAND USE TRENDS

Land utilization of the lower Nisqually and Deschutes Basins will continue to be influenced by the expanding metropolitan cities of Tacoma and Olympia. Suburban developments will continue to utilize portions of the forested benchlands located outside of the boundaries of the Fort Lewis Military Reservation and the Nisqually Indian Reservation. The increasing demand for port facilities capable of handling deep draft vessels will continue to make the river delta north of Interstate Highway 5 attractive for industrial development. In the event that State and local governments decide to develop this area as a deep seaport, the land use in this area will change rapidly from agriculture to industry. The upper portion of the basins are expected to be utilized primarily as a recreation area and as a wood fiber producing area for the forest products industry.

# NISQUALLY RIVER BASIN

## PRESENT STATUS

### Stream System

The Nisqually River originates from glaciers on the southwesterly slopes of Mount Rainier, flows northwesterly 81 miles into Puget Sound, and drains 712 square miles. The main stream is joined by eight tributaries upstream from LaGrande Canyon and five downstream from the canyon. The Paradise River and Tahoma, Kautz and Van Trump Creeks are glacier-fed streams that rise at elevations above 4,000 feet and join the river within Mount Rainier National Park.

From the park boundary to the upstream end of LaGrande Canyon, the river has no important tributaries from the north, but is joined from the south by Big, Mineral, and East Creeks and the Little Nisqually River. Below LaGrande Canyon, the principal tributaries are the Mashel River and Ohop, Tanwax and Muck Creeks from the north, and Yelm Creek from the south.

## Flood Plain

The limits of the 9,000-acre Nisqually River flood plain are shown on Figure 10-1. The entire flood plain is subject to periodic spring and winter flooding; however, flood damage is sustained primarily by recreational developments upstream from Alder Reservoir and agricultural developments in the fertile, 3,000-acre delta.

The narrow flood plain above Alder Reservoir suffers frequent flooding. The steep gradient of the river results in high velocity flows that carry large quantities of gravel, logs and other debris. Developments within Mount Rainier National Park, including the park headquarters at Longmire and Sunshine Park Campground near the park entrance, are within the flood plain. From Mount Rainier National Park to Alder Reservoir, the stream gradient is less severe. During high flows, heavy deposits of bedload and debris fill the channel and force the river to spread over the valley floor. Developments include the park's entrance facilities, summer homes, the Nisqually Park subdivision and Gateway Inn Resort. Transportation facilities include State Highway 7, a county road, and the Chicago, Milwaukee, St. Paul, and Pacific Railroad.

The Alder and LaGrande hydroelectric projects occupy about 11 miles of the Nisqually Valley. These projects, completed in 1945, are owned and operated by the Tacoma Department of Public Utilities. Flood control storage is not provided by either reservoir; however, Alder reservoir operations reduce flood discharges as described in the Flood Control Storage paragraph of this section. Alder reservoir is approximately 7 miles long, covers 3,100 acres, and has a storage capacity of 232,000 acre-feet. The LaGrande project generates power and reregulates discharges from Alder Dam. The reservoir is about 1.5 miles long, covers 45 acres, and has a storage capacity of 2,700 acre-feet.

From LaGrande to the town of Nisqually near the river mouth, a distance of approximately 40 miles, the flood plain is narrow and development is scattered. Vegetation consists primarily of mixed-age stands of timber, with intermittent pasture and cultivated lands. Improvements in this area include a portion of the town of McKenna, a hydroelectric power plant, State Highway 507, two railroad lines, and some county roads. The power plant, about 4 miles downstream from Yelm, is owned and operated by the city of Centralia. Up to a maximum of 600 cfs is diverted from the river above McKenna and carried through a canal to the power plant. The plant has three generating units with a capacity of 9,000 kilowatts.

From the town of Nisqually to tidewater, a distance of approximately 4 miles, the stream flows through a fertile, 3,000-acre delta containing a 40-acre forest nursery, residences, trailer homes and dairy farms, as shown on photograph 10-1. Interstate Highway 5, U.S. Highway 99 and the Northern Pacific Railroad cross the delta.

The production of hydroelectric power, excellent recreation areas in and near Mount Rainier National Park, and the productive agricultural lands in the delta contribute significantly to the basin's economy.

## History of Flooding

**Flood Characteristics**–The runoff pattern of the Nisqually River system parallels those of adjacent rivers, *i.e.*, two distinct peaks each year: one from abundant precipitation falling mainly in the form of rain at lower elevations during the winter months, and the other from melting of the accumulated snowpack in the higher elevations during May and June.

High flows in the fall and winter coincide with periods of maximum precipitation, and are characterized by sharp, extreme rises followed by recessions almost as rapid. Two or more flood peaks often occur within a period of two weeks. Alder Reservoir usually is drawn down about 40,000 to 100,000 acre-feet during December through March, and is filled during May and June to meet power demands. Flood control storage is not provided, but operation of this project reduces flood peaks on the Nisqually River downstream from the LaGrande reregulating reservoir. Large quantities of glacial melt water from the slopes of Mount Rainier contribute significantly to summer flows. The mean low flow period is during August and September. These runoff patterns are illustrated in Figures 10-3 and 10-4. The gage near the town of National was selected to illustrate runoff character-

PHOTO 10-1. View looking south at the tidal flats, agricultural lands, and transportation facilities on the delta area at the mouth of the Nisqually River.

istics because it is upstream from Alder Reservoir and does not reflect the regulatory effects of reservoir operations.

**Floods**–Flows of the Nisqually River have been recorded intermittently since 1907. Continuous records are available from 1942 for the gage near National and from 1947 for the gage at McKenna.

About 18,000 cfs at McKenna is considered to represent the zero damage flow on the Nisqually River. From 1948 through 1965, the river has exceeded zero damage flow at least four times. Flows exceeding 26,000 cfs at this gage cause major damage. Since 1948, this flow has not been exceeded; however, the flood of 29 January 1965 approached this point with a peak discharge of approximately 25,700 cfs. Peak discharges greater than zero damage flow for the Nisqually River at McKenna are tabulated in Table 10-5.

**TABLE 10-5. Peak discharges greater than zero damage (18,000 cfs at McKenna)**

| Discharge (cfs) | Date |
|---|---|
| 25,700 | 29 January 1965 |
| 22,300 | 23 December 1964 |
| 20,500 | 23 November 1959 |
| 20,200 | 12 December 1955 |

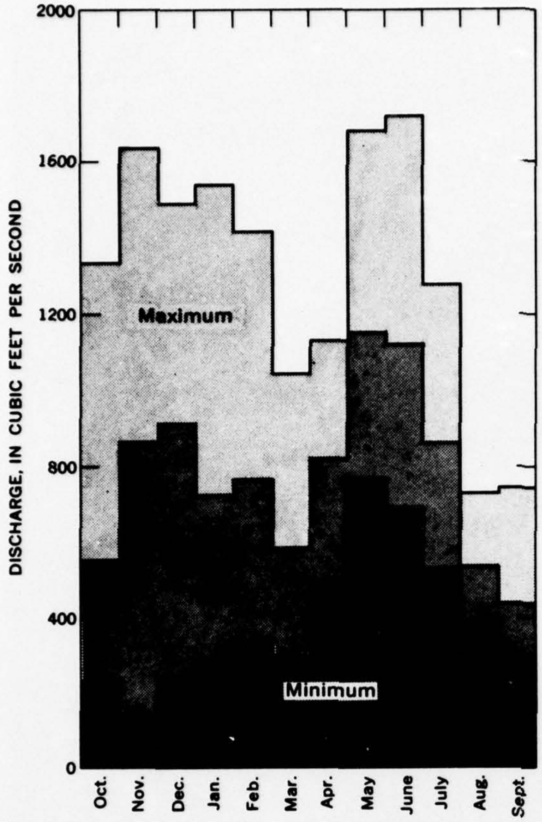



FIGURE 10-3. Maximum, mean, and minimum monthly discharges, Nisqually River near National, 1931-60.

The largest floods for the period of record at McKenna are shown in Table 10-6 with their probable recurrence intervals.

**TABLE 10-6. Major floods and damages**

| Date | Peak Discharge at McKenna (cfs) | Average Recurrence Interval (Years) | Current Estimated Damages |
|---|---|---|---|
| 29 Jan. 1965 | 25,700 | 20 | $140,000 |
| 23 Dec. 1964 | 22,300 | 13 | 50,000 |
| 23 Nov. 1959 | 20,500 | 10 | 40,000 |
| 50 yr. flood | 33,000 (Est.) | 50 | 475,000 |
| 100 yr. flood | 39,500 (Est.) | 100 | 930,000 |

Figure 10-5 and 10-6 are probability curves for annual maximum flows of the Nisqually River at National and McKenna.

**Flood Damages**—In 1966, a detailed examination was made of the flood plain and an estimate prepared of the damage that would be caused by discharge of various magnitudes. Table 10-6 gives peak discharges of the largest floods of record, estimated discharges of the 50 and 100-year floods, and estimated damages at 1966 prices and conditions. Average annual flood damages are estimated to be $31,000 for the Nisqually River flood plain, most of which are to agricultural lands and buildings in the delta. Flooding also damages recreation and transportation facilities and flood protective works. Table 10-7 lists the categories of general flood damages described in the Puget Sound Area Section of this appendix and the percentage of total damage caused by major floods in each category.

**TABLE 10-7. Flood damage distribution Nisqually River**

| | Percent of Total Damage |
|---|---|
| Agriculture | 36 |
| Buildings and equipment | 17 |
| Parks and fish habitats | 16 |
| Transportation facilities | 14 |
| Other | 17 |
| Total losses and damages | 100% |

## Existing Flood Control Measures

**Flood Forecasting and Warning**—The U.S. Weather Bureau forecasts floods. Detailed information is contained in the Puget Sound Area Section of this appendix.

**Flood Protective Works**

**Levees**—Levees within Mount Rainier National Park partially protect Park headquarters, Longmire Lodge and the Sunshine Park Campground. The levee at Longmire is approximately 600 feet long and 4 feet high, and is composed of river-run gravel and boulders. The levee at Sunshine Campground is about 800 feet long and 4 feet high, has a rounded cross-section, and was constructed from river gravel varying from 2 to 8 inches in diameter. Both levees are susceptible to damage from frequent changing of the river channel.

A levee approximately 2,000 feet long provides protection from moderate floods for entrance facilities at Mount Rainier National Park, the Gateway Inn Resort, and the Nisqually Park subdivision. The levee is about 10 feet high, has a top width of about 12

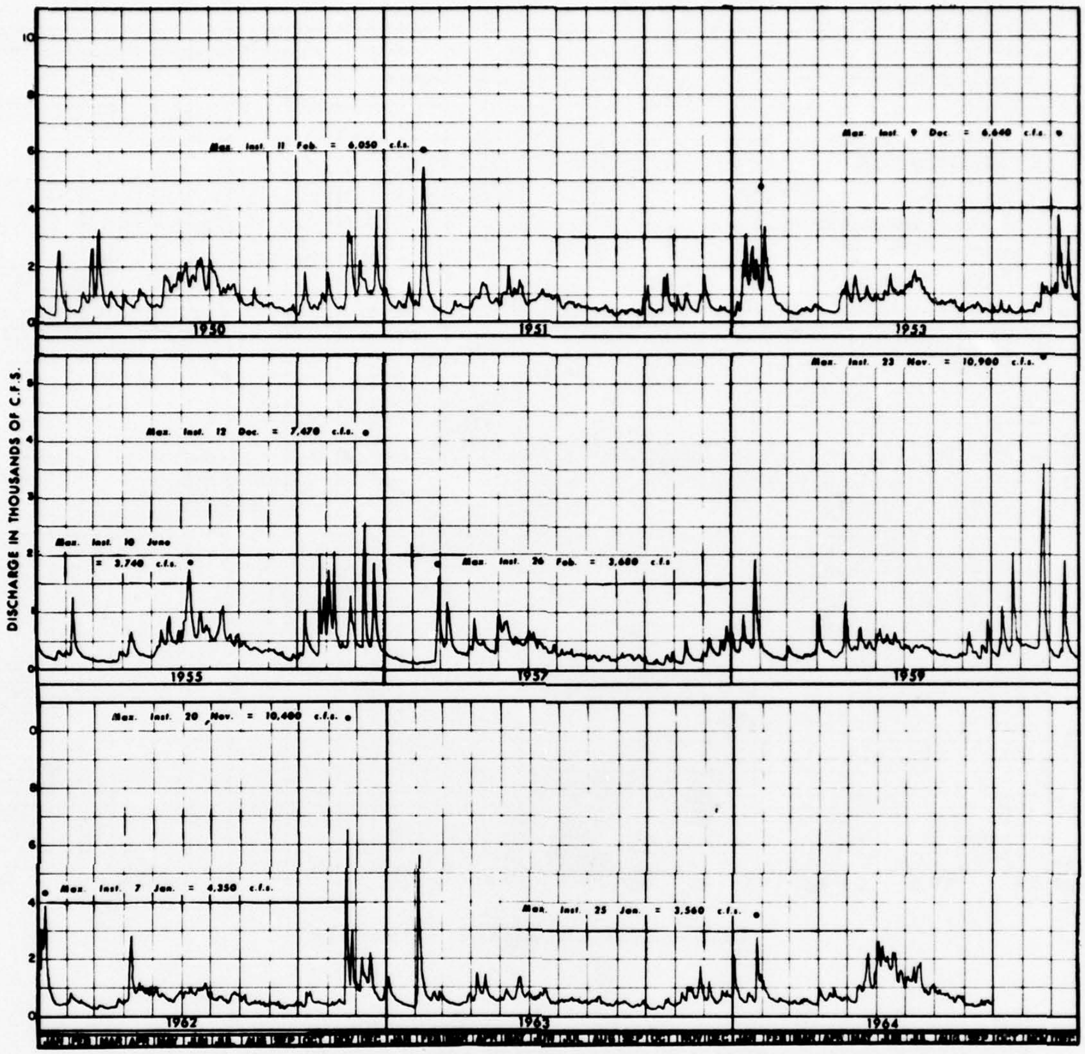



**FIGURE 10-4. Daily discharge hydrograph, Nisqually River near National.**

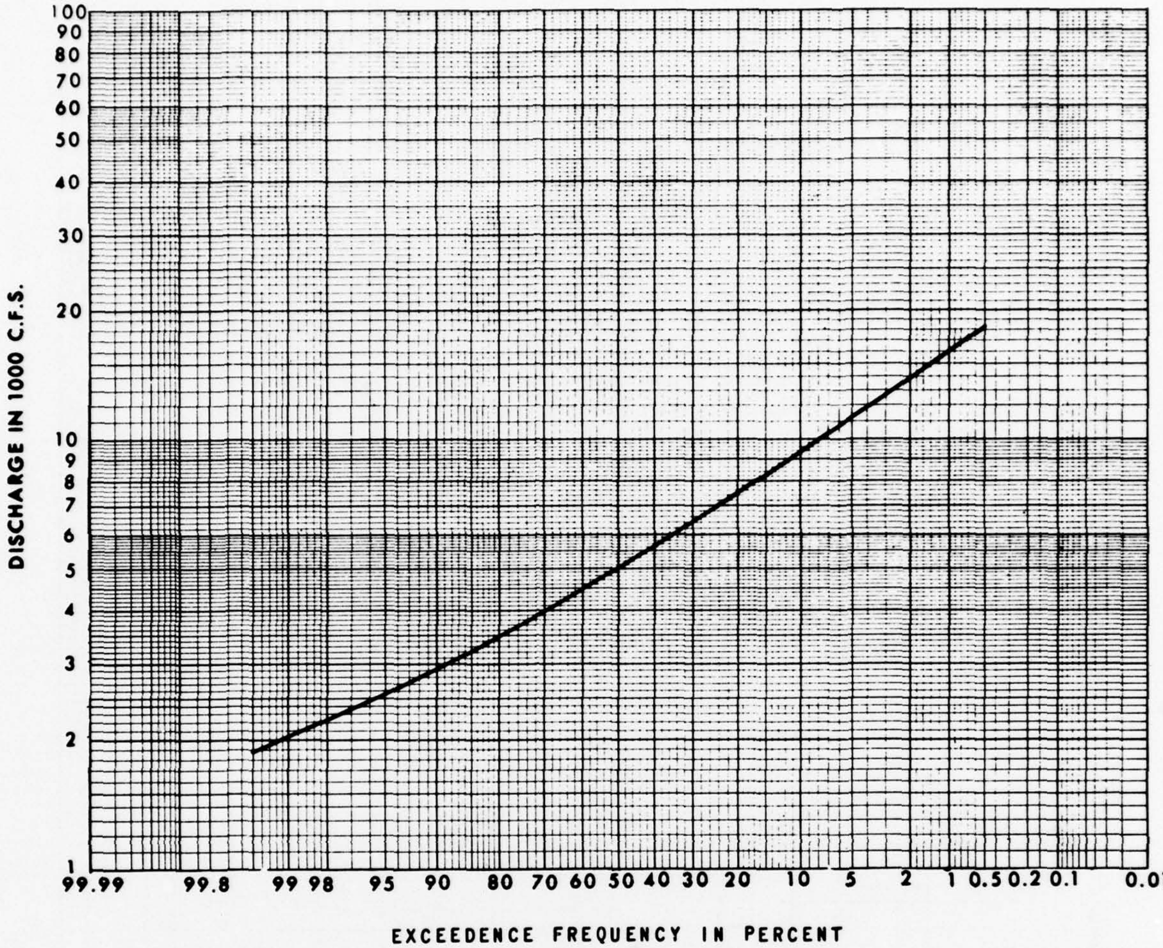



**FIGURE 10-5. Frequency curve of annual maximum peak flows, Nisqually River near National**

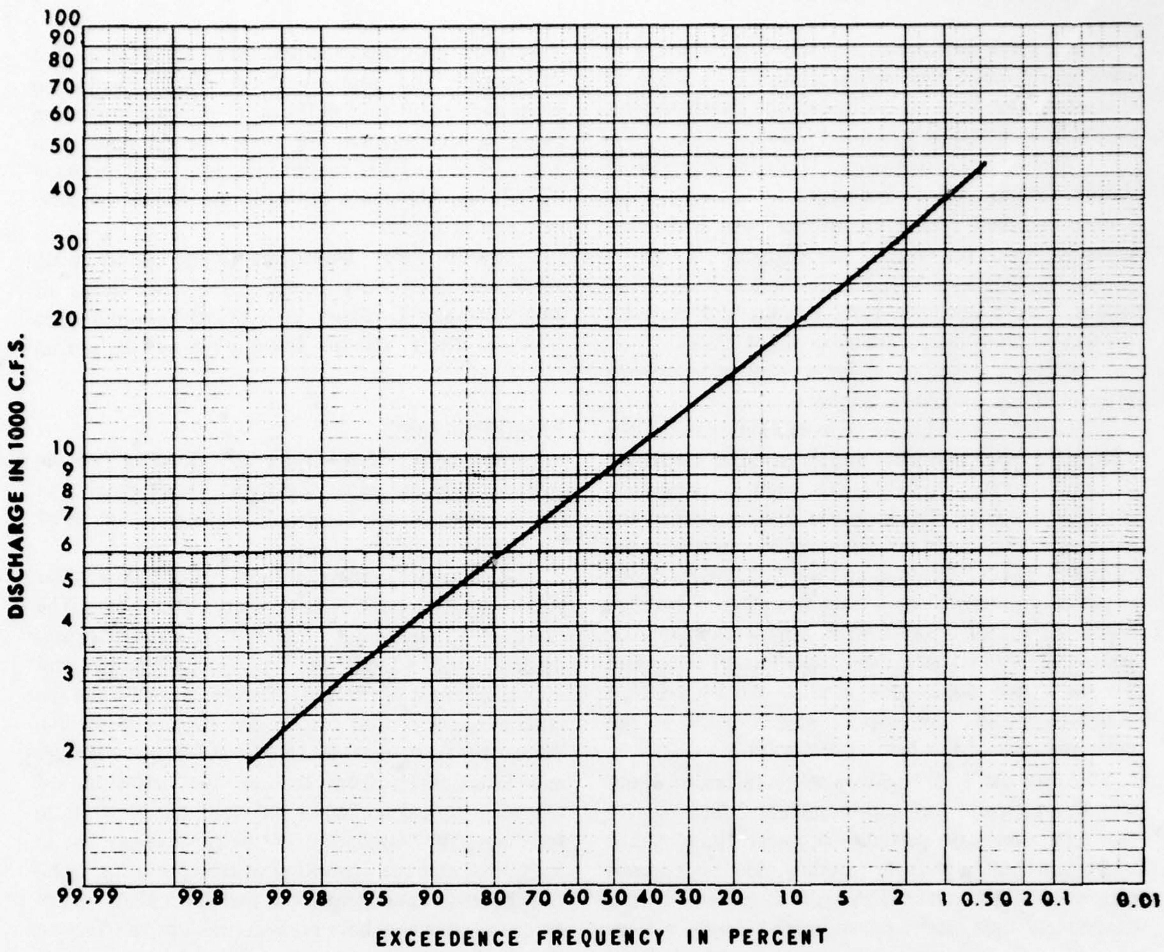



**FIGURE 10-6. Frequency curve of annual maximum peak flows, Nisqually River at McKenna**

feet and 1½:1 side slopes, and was constructed with river gravel faced with riprap from 1½ to 3 feet in diameter. The levee has stabilized the riverbank, but would be overtopped by a major flood.

A portion of the town of McKenna is protected from moderate flood discharges by a small levee several hundred feet long on the right bank that extends upstream from the highway bridge at McKenna. This levee varies from three to four feet in height, has a variable cross-section, and provides protection from discharges up to about 25,000 cfs on the McKenna gage, or a flood with a recurrence interval of approximately 20 years.

Levees with varying cross-sections protect the rich delta from high tides and from flood discharges of approximately 18,000 cfs with a recurrence interval of 7 years. The homesite development on the east side of Interstate Highway 5, between the Northern Pacific Railroad and old U.S. Highway 99, is partially protected by a levee from 2 to 4 feet high along the top of the riverbank. This levee is approximately 2,000 feet long, has a top width of 6 feet and 1½ on 1 side slopes, and is protected by 1½ foot diameter riprap. The top of this levee is at the crest elevation of the January 1965 flood.

From old U.S. Highway 99 to Interstate Highway 5, a concrete wall approximately 2 feet high on the left riverbank partially protects three 4-unit apartment buildings from flooding. The agricultural area west of Interstate Highway 5 is protected from moderately high discharges and high tides by a levee about 7 miles long with a maximum height of about 10 feet, has a top width of about 10 feet, and is generally not protected by riprap.

**Bank Protection**–Bank protective works, 2,720 feet long along the Nisqually River near the town of Elbe provide protection to a bridge and its approaches on State Highway 7. This project, sponsored by Lewis County, was completed in 1948 by the U.S. Army Corps of Engineers at a cost of $57,100.

About 700 feet of the left bank of the river just above the old Pacific Highway bridge are protected by rock riprap. This project, sponsored by Thurston County, was constructed in 1960 by the U.S. Army Corps of Engineers at a total cost of a $29,800.

**Flood Control Storage**–The Alder Dam Project does not provide for firm flood control storage. However, when a flood is expected and Alder Reservoir is at maximum pool elevation, the reservoir is drawn down about 4 to 6 feet. This amount of drawdown provides from 10,000 to 15,000 acre-feet of storage and reduces flood discharges by an estimated 3,000 to 5,000 cfs. The normal operating range of the reservoir for power production varies from elevation 1,114 feet to maximum pool elevation 1,207 feet. This range in elevation contains 147,000 acre-feet of storage.

**Flood Plain Management**–The flood plain management services provided by the Corps of Engineers are discussed in the Puget Sound Area Section. There are no flood plain regulations in effect.

## Flood Problems

**Nisqually River**–Overbank flooding occurs frequently above Alder Reservoir. Developments in the flood plain are hampered because of the flood threat.

Overbank flooding along the river below Alder Reservoir occurs about once every seven years. The flood of 22 December 1933 had an estimated peak discharge of 42,000 cfs at the rivermouth and inundated most of the delta. Damage begins when the flow exceeds 18,000 cfs on the gage at McKenna. When the flow exceeds 26,000 cfs, major damages and losses result from erosion: the deposition of debris on agricultural lands and water damage to farm buildings, the inundation of urban development in McKenna, and the disruption of transportation facilities. Because developments in the flood plain are not extensive, damages have no major disruptive effect on the basin's total economy. Flood waters recede quickly and emergency repairs to essential facilities are accomplished rapidly.

**Tributary Streams**–Muck Creek flows about 15 miles in a westerly direction and discharges into the Nisqually River about two miles south of Nisqually Lake. Lacamas Creek enters Muck Creek near the town of Roy. Drainage patterns are poorly defined, and overbank flooding occurs, particularly near the town of Roy.

Horn and Tanwax Creeks are south of and adjacent to Lacamas Creek and Muck Creek. Tanwax Creek originates in Tanwax Lake and flows in a southwesterly direction for approximately 12 miles to its junction with the Nisqually River. Horn Creek originates northwest of Tanwax Creek and flows about 8 miles in a southwesterly direction to the Nisqually River. These drainages also have rolling topography with poorly defined drainage patterns and sustain overbank flooding. Landowners in the

upper Muck, Lacamas, Horn and Tanwax watersheds have indicated interest in forming a flood control and drainage zone district.

Ohop Creek rises about a mile south of Lake Kapowsin and flows southwesterly 4 miles to Ohop Lake, thence 5 miles to the Nisqually River. The upper reach of the flood plain is about one-fourth mile wide and subject to overbank flooding. Local interests have requested assistance from the Soil Conservation Service under the provisions of Public Law 566.

The Mashel River originates in heavily forested, mountainous country at about elevation 4,000 feet. The river flows in a northwesterly direction for a distance of approximately 25 miles and enters the Nisqually River near the community of LaGrande. Eatonville, which has over 75 percent of the population in this watershed, is on the right bank of the Mashel River about four miles above its junction with the Nisqually. The Mashel is a swift river during high runoff and has washed out portions of county roads. Streambank erosion is severe during flood discharges.

## PRESENT AND FUTURE NEEDS

### Evaluation of Present Situation

The 9,000-acre flood plain of the Nisqually River is subject to frequent flooding. The flood plain above Alder Reservoir is utilized primarily for recreation-oriented developments. Levees provide some protection to Longmire and the Sunshine Park Campground in Mount Rainier National Park, but would be damaged or overtopped by major floods. The low levee that protects entrance facilities of Mount Rainier National Park, the Gateway Inn Resort and the Nisqually Park subdivision from moderate floodflows has stabilized the riverbank, but would be overtopped by a major flood.

Below Alder Reservoir overbank flooding occurs when flows exceed 18,000 cfs. This flow has a recurrence frequency of about once in seven years. The town of McKenna and much of the agricultural delta are partially protected by levees of varying cross-sections.

No firm flood control storage exists at Alder or LaGrande Reservoir, but the Tacoma Department of Public Utilities operates Alder Reservoir to provide some flood control storage. The amount of storage provided, however, is not sufficient to appreciably reduce major flood discharges. About 40,000 acre-feet of storage would be required to realize 25-year flood protection for the delta.

Levees along the Nisqually River were constructed piecemeal by private landownders to alleviate localized flooding, and are incapable of providing protection against major floods. The flood hazard restricts use of the flood plain to recreational and agricultural developments that can withstand frequent flooding. Overbank flooding also occurs along the following tributaries: Muck, Horn, Tanwax, and Ohop Creeks, and the Mashel River.

### Flood Control Needs

**Prevention of Flood Damages**—Average annual damages are estimated to be $31,000 under 1966 conditions and the damages that would result from a flood with an estimated frequency of 100 years is estimated to be $930,000.

Based on methodology and considerations previously discussed for the Puget Sound Area, anticipated flood damages in the flood plains of the Nisqually River Basin are expected to increase by the percentages as shown in Table 10-8.

**TABLE 10-8. Percentage increases in productivity levels and developments for specified periods**

| Category of Damage | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Agriculture | 20 | 29 | 29 |
| Non-Agriculture | 20 | 60 | 60 |

Application of these percentages to the average annual damages based on 1966 prices and conditions provides an indication of future damages at 1966 prices if additional flood protection is not provided. Table 10-9 shows that the combination of all categories of damage are expected to increase from about $31,000 in 1966 to $83,000 by the year 2020.

#### Optimum Flood Plain Use

**Recreation**—The flood plain of the Nisqually River, particularly upstream from Alder Reservoir, has potential for extensive recreational developments. A level of flood protection exceeding 10 years is required to permit construction of restrooms, picnic tables, tree plantings and other park facilities. Summer homes and other dwellings must be located out of the flood plain or provided a higher level of protection.

TABLE 10-9. **Existing and future annual damages (in thousands of dollars).**

| Category | Under Development Levels of 1966 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Agriculture | 12 | 13 | 17 | 22 |
| Buildings & Equipment | 5 | 6 | 10 | 16 |
| Transportation Facilities | 4 | 5 | 8 | 13 |
| Recreation | 5 | 6 | 10 | 16 |
| Other | 5 | 6 | 10 | 16 |
| Total | 31 | 36 | 55 | 83 |

**Agriculture**–Production of agricultural lands must be increased to meet future food and fiber needs of the Puget Sound Area. This increase in agricultural production would require at least a 25-year level of flood protection particularly to the 4,500 acre delta area at the river's mouth.

**Intensive Land Use**–In the event that State and local governments develop a deep sea port at the mouth of the Nisqually River, flood protection in excess of 100 years must be provided. Port facilities, transportation facilities, and port-oriented industrial sites could require an estimated 3,000 acres north of Interstate Highway 5.

### Summary of Flood Control Needs

The 9,000 acre flood plain of the Nisqually River needs increased flood protection for existing developments. Average annual flood damages are estimated to be $31,000 under 1966 conditions and the damages that would result from a flood with an estimated frequency of 100 years is estimated to be $930,000.

Anticipated growth in the flood plain indicates that future flood damages will increase if additional protection is not provided. Average annual damages under future conditions are estimated to be $36,000 in 1980, $55,000 in 2000, and $83,000 in 2020 if additional protection is not provided.

Agricultural lands need a 25-year level of flood protection to allow for increased economic returns from the land. Flood control is also needed for recreational facilities particularly in the area above Alder Reservoir. In the event that a deep sea port is constructed at the Nisqually River delta area, protection in excess of 100 years will be required. Structural flood control measures should be provided to the maximum extent that economics will permit and land areas should be managed to permit development commensurate with the flood protection provided.

## MEANS TO SATISFY NEEDS

### Flood Control Objectives

The flood control objective is to satisfy the needs described in the previous section by providing flood control by structural measures commensurate with economic justification and by managing the flood plain consistent with the flood protection provided.

Agricultural lands in the flood plain below Alder Reservoir should be provided 25-year flood protection and the small town of McKenna should be provided 100-year protection.

In the event that State and local governments elect to construct a deep sea port at the Nisqually River delta, protection in excess of 100 years would be required.

### Opportunities for Structural Measures

**Upstream Storage**–Construction of flood control storage to protect the narrow flood plain located above Alder Reservoir is not economically feasible. Inclusion of flood control storage in the existing Alder Reservoir, to provide protection in excess of 100-years to the flood plain below Alder Reservoir, is physically possible. Storage of 74,000 acre-feet is contained above the spillway elevation of 1177.0 feet and is suitable for flood control purposes. Approximately 55,000 acre-feet of flood control storage would be required to control a flood with an estimated average frequency of recurrence of 100 years to zero damage flow of 18,000 cfs measured at the gage near McKenna.

**Levees**–No extensive levee construction can be economically justified in the foreseeable future. In the event that a port facility is constructed at the mouth of the Nisqually River, flood protection in excess of 100 years could be provided by channel and levee construction. Cost and economic justification for flood control are dependent upon the location and physical layout of the port facilities.

### Solutions to Flood Control Needs

**General**–Features of the flood control plan are detailed in Table 10-10 and shown in Figure 10-7. Upstream storage, levees, and flood plain management are the nucleus of this plan. The features of the flood control plan are described as single-purpose flood control and would provide for optimum development and protection through the year 2020.

**TABLE 10-10. Flood control plan**

| Flood Control Feature | Effective Storage Acre-Feet | River Mile | Sequence of Development To 1980 | To 2000 | To 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|---|---|
| Flood Control Storage | | | | | | |
| Alder Reservoir | 55,000 | 35 | | X | | Existing Project[1] |
| Levees & Channelization | | | | | | |
| Nisqually River delta area | | | | | X | $3,000,000 |
| Flood Plain Management | | | X | X | X | 43,000[2] |
| | | | | Total Cost of Plan | | $3,043,000 |

[1] Power losses resulting from including flood control storage as a project purpose in the existing Tacoma Department of Public Utilities Alder Reservoir will require evaluation by owner.

[2] Includes estimated cost of a Flood Plain Information Study and flood plain zoning and regulation implementation costs.

Economic justification may depend upon consideration of other water resource needs.

**Sequence of Development**

**To 1980**—No structural flood protective works would be economically justified. Flood plain management should be implemented to restrict developments in the flood plain to those which are commensurate with the flood hazard.

**1980-2000**—Flood control storage could be added as a project purpose in the Tacoma Department of Public Utilities' Alder Reservoir. Flood plain regulations should be continued.

**2000-2020**—In the event that it is decided to construct a port facility at the delta area near the mouth of the Nisqually River, levees and channelization could be constructed to provide this area with flood protection which would permit intensive use. Flood plain management and regulations should be continued.

**Accomplishments**—Upstream storage in Alder Reservoir would provide up to 100-year protection to the 8,000-acre flood plain below Alder Dam and permit reasonable agricultural returns. Levees and channelization in combination with upstream storage or as an alternative to flood control storage could be constructed to give protection in excess of 100 years to the delta at the riversmouth in the event a port is established.

**Alternatives Considered**—Floodproofing of existing buildings was evaluated as an alternative to major flood protective works for reduction of present and future flood damages. Approximately 15 percent of the estimated $31,000 average annual flood damages or about $5,000 occurs to buildings. A high percentage of these buildings cannot be economically flood proofed because they are of wood frame construction and would require structural treatment. This alternative would not meet the present or future needs for optimum development and utilization of the Nisqually Basin flood plain.

## Summary

Overbank flooding occurs frequently above Alder Reservoir. Overbank flooding along the river below Alder Reservoir occurs on a frequency of about once every seven years and damage begins when flows exceed 18,000 cfs at the gage near McKenna. Average annual flood damages are estimated to be $31,000 and the damage that would result from a flood with an estimated recurrence interval of 100 years is $930,000.

Future average annual flood damages may be expected to increase in proportion to the increase in economic activity in the flood plain if additional protection is not provided. The trend of development would result in future growths of flood damages

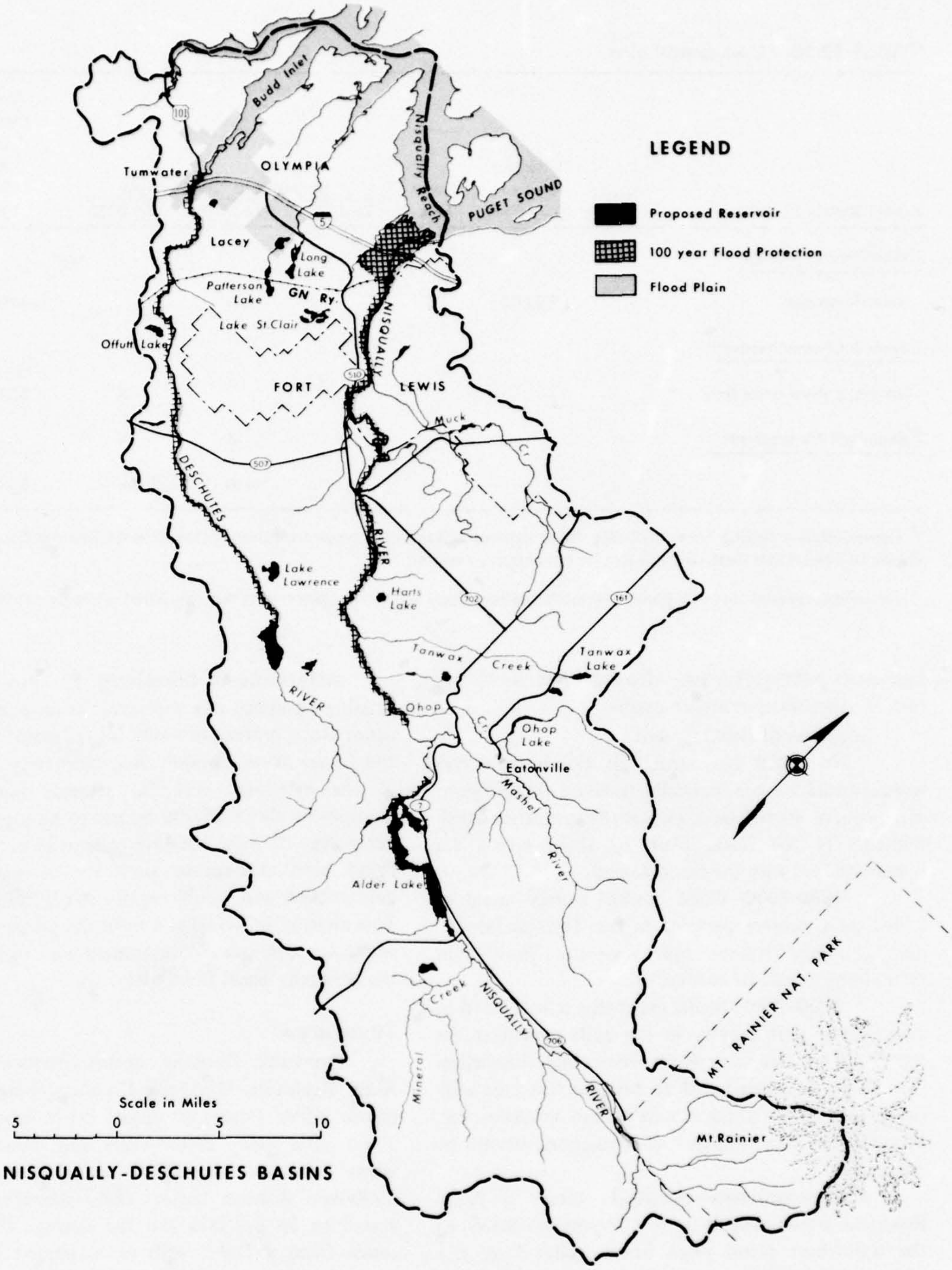



**FIGURE 10-7 Proposed flood control plan and accomplishments**

approximating 1-7/8 percent compounded annually without flood control and would result in future growth of annual damages to $36,000 in 1980, $55,000 in 2000, and $83,000 in 2020.

Implementation of the flood control plan will significantly reduce flood plain damages and permit increased utilization of the flood plain. The inclusion of flood control storage as a project purpose in the existing Alder Reservoir would provide 100-year protection to the downstream flood plain. Levee and channelization could also provide protection in excess of 100 years to the delta area. Flood plain regulation and management commensurate with the protection provided would minimize flood damages.

# DESCHUTES RIVER BASIN

## PRESENT STATUS

### Stream System

The Deschutes River rises at elevations approaching 4,000 feet on the western slope of the Cascade Range, flows northwesterly about 45 miles, and empties into Budd Inlet, an arm of Puget Sound, at the city of Olympia. The river drainage comprises an area of 162 square miles. The Deschutes flows parallel to the Nisqually River and occupies a portion of the benchland common to both streams. The principal tributaries are Spurgeon Creek and the Little Deschutes River from the north, and Thurston, Mitchell and Lincoln Creeks from the south.

### Flood Plain

The 2,700-acre flood plain, shown in Figure 10-1, contains 1,200 acres of cultivated agricultural land, urban, suburban and industrial development, and transportation facilities that are subject to periodic winter and spring flooding. Transportation facilities include Interstate Highway 5, U.S. Highways 99 and 410, State Highway 507, and three transcontinental railroads: the Great Northern, the Chicago, Milwaukee, St. Paul and Pacific, and the Northern Pacific. Four railroad, three highway and 11 county road bridges cross the Deschutes River.

The narrow, upper flood plain contains agricultural land of fair quality and a subdivision of 40 newly-constructed summer homes and lots for sale primarily in the vicinity of Lake Lawrence.

Development in the lower flood plain includes about 40 newly-constructed residences in a suburban development at Tumwater and part of the Olympia Brewery plant. Warehouses, water wells, a parking area, and a footbridge at the brewery are within the flood plain and subject to flood damage. Most of the development in the city of Olympia is outside the flood plain.

### History of Flooding

**Flood Characteristics**–The Deschutes River is primarily a rainfed stream and has a high base flow during the winter months. Peak flows may occur from November through March and are characterized by sharp, extreme rises followed by a recession almost as rapid.

Riverflow is measured at a gaging station near Olympia. The flow averages about 200 cfs during June and July, decreases to an average of 100 cfs in August and September and begins to increase in October. The runoff pattern is shown in Figure 10-8 and the daily discharge hydrograph in Figure 10-9. Floodflows during the winter may be eight times greater than the average winter base flow of 700 cfs, as shown in Figure 10-8. The mean discharge of the Deschutes River at Olympia was 390 cfs for the period 1931-1960. Figure 10-10 is a probability curve for annual maximum flows of the Deschutes River near Olympia.

**Floods**–High water flows were recorded on the Deschutes River from 1945 to 1964 at a gage near Olympia, and since 1949 at the gage near Rainier. About 3,500 cfs at Olympia may be considered to represent zero damage flow. Since 1945, this flow has been exceeded at least 14 times. Major damage begins when the flow exceeds 5,400 cfs. Peak discharges greater than zero damage flow during the period of record are tabulated in Table 10-11.

**Flood Damages**–In 1966, detailed examination was made of the flood plain and an estimate prepared of damages that would be caused by discharges of

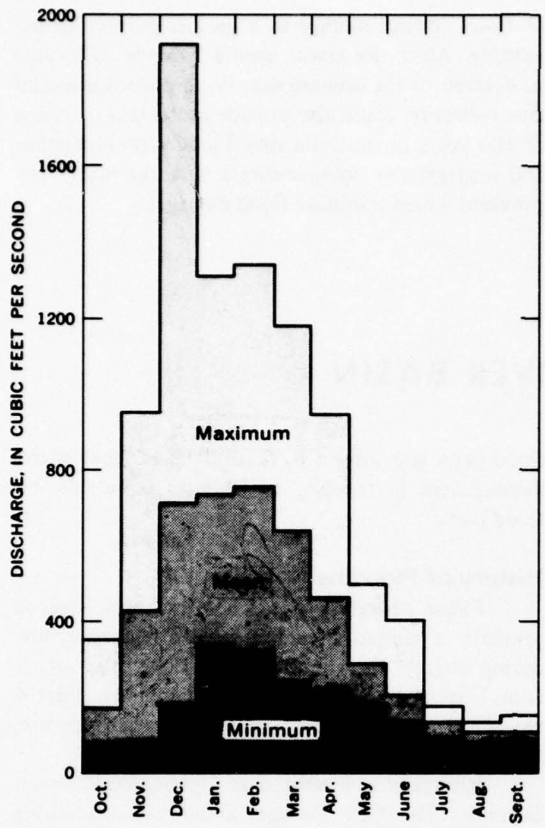



FIGURE 10-8. *Maximum, mean and minimum monthly discharges, Deschutes River near Olympia, 1931-60.*

**TABLE 10-11. Discharges greater than zero damage (3,500 cfs at Olympia)**

| Discharge (cfs) | Date |
|---|---|
| 6,650 | 26 Jan. 1964 |
| 6,080 | 13 Dec. 1955 |
| 5,000 | 26 Nov. 1962 |
| 4,920 | 25 Nov. 1960 |
| 4,780 | 10 Dec. 1953 |
| 4,750 | 26 Jan. 1947 |
| 4,750 | 18 Feb. 1949 |
| 4,600 | 10 Feb. 1951 |
| 4,340 | 4 Feb. 1963 |
| 4,210 | 25 Feb. 1957 |
| 4,080 | 6 Mar. 1950 |
| 3,960 | 28 Dec. 1949 |
| 3,750 | 6 Jan. 1954 |
| 3,540 | 9 Feb. 1955 |

Note: Use of the gage near Olympia was discontinued 30 June 1964.

various magnitudes. Table 10-12 tabulates the peak discharges of past floods, the estimated discharges of the 50-year and 100-year floods and the estimated damages at 1966 prices and conditions. The average annual flood damages for the Deschutes River flood plain are estimated to be $26,000. Most of these damages are to roads, railroads, bridges, buildings, summer homes, residences, the Olympia brewery, a fish egg-taking station and water wells. Table 10-13 lists the categories of general flood damages described in the Puget Sound Area Section of this appendix and the percentage of damage caused by major floods in each category.

**TABLE 10-12. Major floods and estimated damages**

| Date | Peak Discharge at Olympia (cfs) | Recurrence Interval (Years) | Estimated Damages (1966 Prices & Conditions) |
|---|---|---|---|
| Jan. 26, 1964 | 6,650 | 18 | $130,000 |
| Dec. 13, 1955 | 6,080 | 12 | 90,000 |
| Nov. 26, 1962 | 5,000 | 5 | 30,000 |
| 50-year flood | 7,900 | 50 | 240,000 |
| 100-year flood | 8,800 | 100 | 340,000 |

**TABLE 10-13. Flood damage distribution—Deschutes River**

| | Percent of Total Damage |
|---|---|
| Buildings and equipment | 49 |
| Transportation facilities | 26 |
| Agriculture | 20 |
| Other | 5 |
| Total losses and damages | 100 |

## Existing Flood Control Measures

**Flood Forecasting and Warnings**—Specific flood stage forecasts are not issued for the Deschutes River at the present time. Forecasts of heavy rainfall or weather conditions that could produce floods are issued by the Weather Bureau Forecast Office, Seattle, Washington, and are given widespread dissemination over news media. Local officials can interpret these weather forecasts as warnings and act accordingly.

Photographs 10-2 and 10-3 show damage to summer home and agricultural lands as a result of the flood discharge.

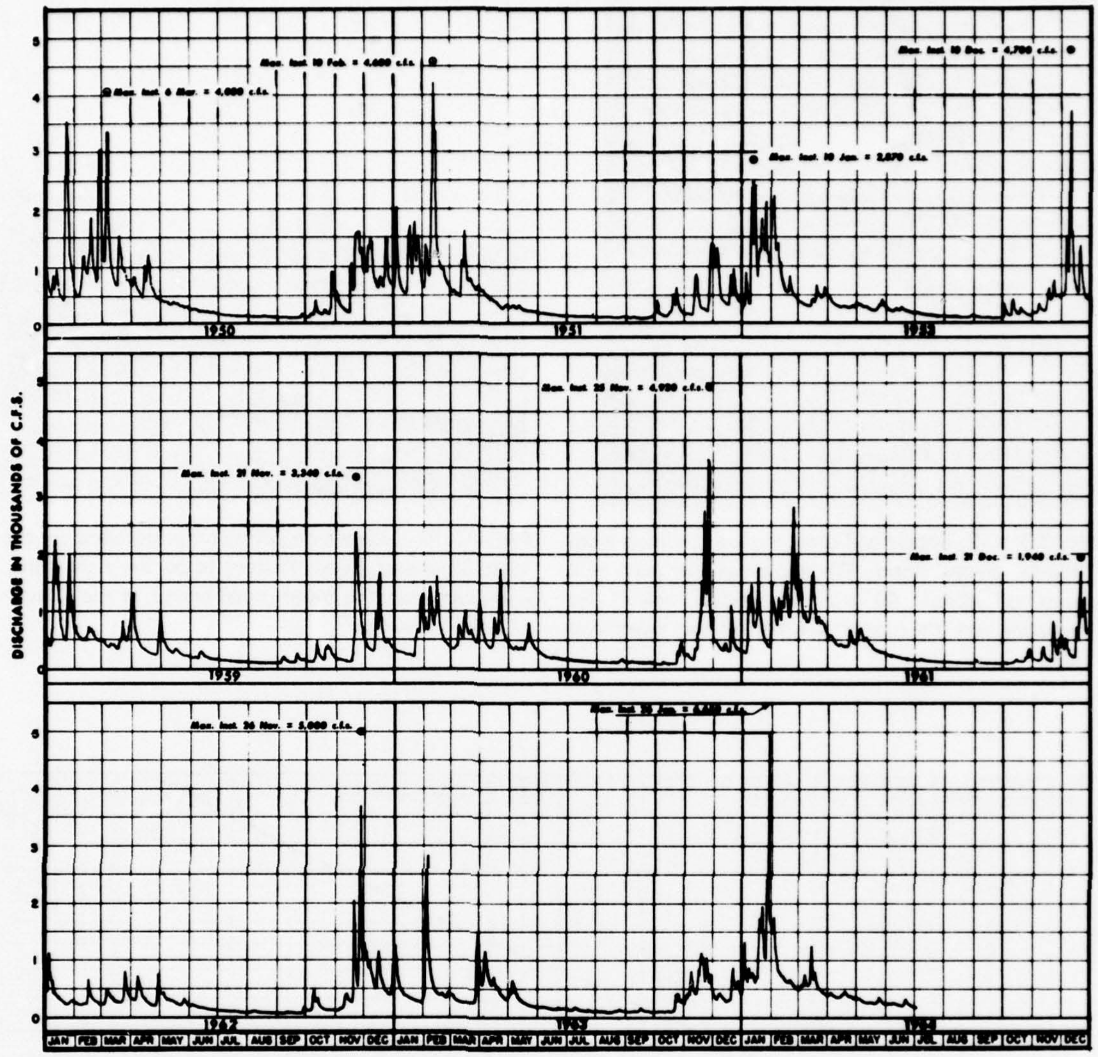



**FIGURE 10-9. Daily discharge hydrograph, Deschutes River near Olympia.**

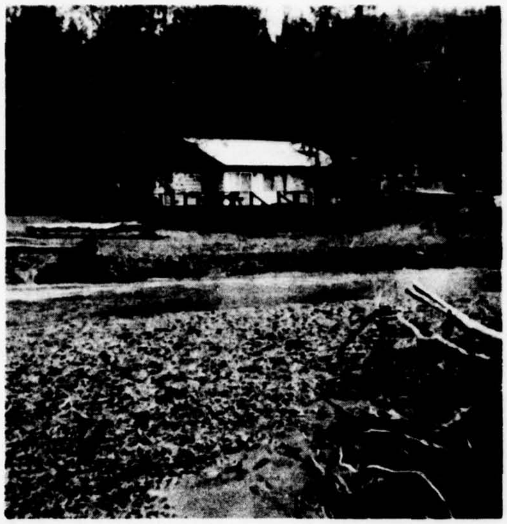


PHOTO 10-2. Debris and bank erosion resulting from 1966-67 winter flood. The buildings are part of a group of about 40 summer homes near Lake Lawrence, on the upper reaches of the Deschutes River.

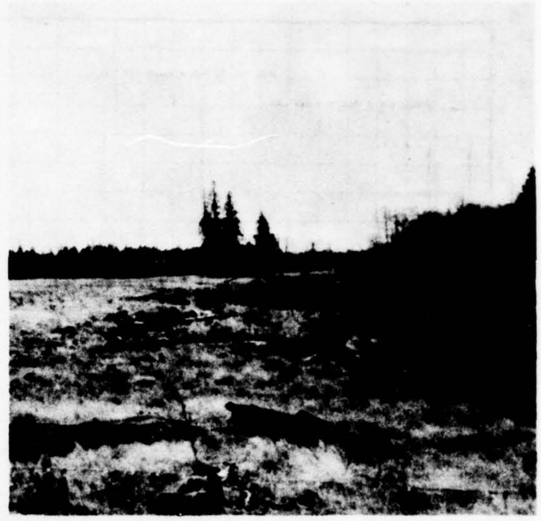


PHOTO 10-3. Debris deposited on pastureland by the 1966-67 winter flood. Pasture is on the right bank, upstream from the county road bridge, in the vicinity of Lake Lawrence.

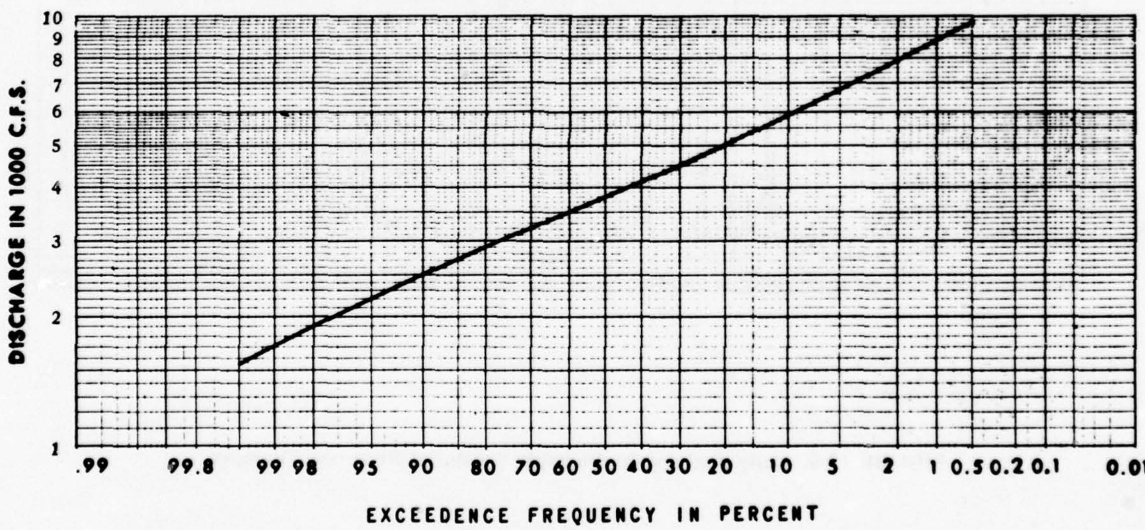



**FIGURE 10-10. Frequency curve of annual maximum peak flows, Deschutes River near Olympia**

**Flood Protective Works**

**Levees**—The Olympia Brewing Company constructed a fill and levee along the right bank of the Deschutes River to enlarge a parking and service area adjacent to the company's original plant.

**Bank Protection**—Bank protective works to protect the Gleason Road bridge, two miles southeast of Tumwater, were completed in August 1965. This work consisted of sloping and revetment of 550 feet of the streambank at a total cost of about $31,300.

Bank protective work to protect the Rich Road bridge, about 3 miles southwest of East Olympia, was completed in July 1967. This work consisted of approximately 500 feet of sloping and revetment on the right bank at a Federal cost of $23,000.

**Flood Plain Management**—There are no flood plain regulations in effect that restrain developments in flood prone areas.

## Flood Problems

The Deschutes River is primarily a rainfed stream. During the summer, discharges and velocities are low. Heavy precipitation in the winter months causes sudden rises and overbank flows. There are no storage reservoirs in the basin to regulate streamflow, and very little bank protection or other flood control works along the river. Flooding damages developments in the vicinity of Lake Lawrence and threatens new urban and long-established industrial development in Tumwater.

# PRESENT AND FUTURE NEEDS

## Evaluation of Present Situation

The 2,700-acre flood plain of the Deschutes River is utilized for forestry, agriculture, summer homes, and urban and industrial development. Damage begins when riverflow approximates 3,500 cfs at Olympia. Average annual damages are estimated to be $26,000. Flooding damages agricultural lands, residences, urban and industrial development, utilities and transportation facilities. Damages to agricultural lands include erosion and the deposition of debris.

Existing protective works consist of a small levee at the Olympia Brewery plant and bank protection at several bridges. These works were constructed solely to alleviate localized flooding. There are no storage reservoirs to regulate flows. Discharges at Olympia fluctuate widely, from a maximum of about 6,600 cfs in the winter months to a minimum of less than 200 cfs in late summer. Increased flood protection is necessary before the flood plain can be utilized to its full potential.

## Flood Control Needs

**Prevention of Flood Damages**—The 2,700-acre flood plain of the Deschutes River suffers average annual flood damages estimated at $26,000 and the damages that would result from a flood with an estimated frequency of 100 years is estimated to be $340,000. These losses could be reduced by increasing the level of flood protection. Flood plains must be zoned to insure that future development of these lands is orderly and consistent with the protection provided.

Based on the methodology and considerations previously discussed for the Puget Sound Area, anticipated flood damages in the flood plains of the Deschutes River Basin are expected to increase by the percentages as shown in Table 10-14.

**TABLE 10-14. Percentage increases in productivity levels and developments for specified periods**

| Category of Damage | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Agriculture | 20 | 29 | 29 |
| Non-Agriculture | 20 | 60 | 60 |

Application of these percentages to the average annual damages based on 1966 prices and conditions provides an indication of future damages at 1966 prices if additional flood protection is not provided. Table 10-15 shows that the combination of all categories of damage are expected to increase from about $26,000 in 1966 to $76,000 by the year 2020.

**TABLE 10-15. Existing and future annual damages (in thousands of dollars)**

| Category | Under Development Levels of 1966 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Agriculture | 5 | 6 | 8 | 10 |
| Buildings & Equipment | 13 | 17 | 26 | 41 |
| Transportation Facilities | 7 | 10 | 15 | 22 |
| Other | 1 | 1 | 2 | 3 |
| Total | 26 | 34 | 51 | 76 |

#### Optimum Flood Plain Use

**Recreation**–The upper reaches of the Deschutes River flood plain have potential for extensive recreation developments such as campgrounds, picnic areas, and summer dwellings. Increased flood protection is required before increased recreational summer home development can be accomplished.

**Agriculture**–Increased production from lands remaining in agriculture will be required and the level of flood protection should be increased to at least twenty-five years where economically justified.

**Intensive Land Use**–Urban and suburban development of flood plain lands near Olympia and Tumwater will require 100-year flood protection. Suburban development is presently occurring in the town of Tumwater without adequate flood protection.

### Summary of Flood Control Needs

The need for additional area suitable for urban and suburban expansion in and around Olympia and Tumwater will require that flood plain lands be provided additional flood protection. The demand for developed recreational stream frontage for summer home development will require that additional flood protection be provided. Structural flood control measures should be provided to the maximum extent that economics will permit and land areas should be managed to permit developments commensurate with the flood protection provided.

## MEANS TO SATISFY NEEDS

### Flood Control Objectives

The flood control objectives are to satisfy the needs described in the previous section by providing flood control by structural measures commensurate with economic justification and by managing the flood plain consistent with the flood protection provided.

Agricultural lands could be provided 25-year protection and residential and industrial areas in the town of Tumwater and the city of Olympia could be provided 100-year protection.

### Opportunities for Structural Measures

**Upstream Storage**–A storage site exists near Shellrock Ridge on the Deschutes River. An estimated 15,000 acre-feet of flood control storage would be required to control a flood with an estimated average recurrence interval of 100 years to zero damage flow of 3,500 cfs measured at the gage near Olympia.

**Levees and Channelization**–In 1968 the Olympia Brewing Company began construction of a large recreation area, including a golf course, located on a portion of both sides of the Deschutes River, extending from the Olympia Brewery upstream to the Gleason Road, a distance of about two miles. Channel improvements along this river reach, including riprapping and seeding streambank slopes, are being performed. Completion of this project is expected to give protection in excess of 50 years to developments on the flood plain in this area. Other channel and levee improvements may be economically justified along individual portions of the flood plain in the future.

### Solutions to Flood Control Needs

**General**–Features of the flood control plan are detailed in Table 10-16. Flood plain management is the nucleus of this flood control plan. In the event that pressure for intensive use of the flood plain occurs, levees and channelization or upstream storage could be constructed to provide additional protection.

#### Sequence of Development

***To 1980***–*Flood plain regulation and zoning* should be implemented so that future developments are commensurate with the flood protection provided.

**1980-2020**–Upstream flood control storage could provide protection in excess of 100 years to the flood plain if demand for intensive use of these lands occurs. Additional protection could also be provided by levee construction and channelization.

**Accomplishments**–Flood plain management could control developments in the flood plain and minimize future flood damages. Channel improvements by the Olympia Brewing Company along the 2.5 mile river reach downstream from the Gleason Road to the Olympia Brewery could provide protection in excess of 50 years to this portion of the flood plain which includes a suburban development of of the town of Tumwater.

**Alternatives Considered**–Floodproofing of existing buildings was evaluated as an alternative to major flood protective works for reduction of present and future flood damages. Approximately 40 percent of the estimated $26,000 average annual flood

TABLE 10-16. Flood control plan

| Flood Control Feature | Effective Storage Acre-Feet | Height of Dam Feet | Sequence of Development To 1980 | To 2000 | To 2020 | Estimated Development Costs for Project Based on 1968 Prices |
|---|---|---|---|---|---|---|
| Flood Control Storage Projects | | | | | | |
| Shellrock Ridge Storage Dam | 15,000 | 115 | | | X | $3,500,000 |
| Flood Plain Management | | | X | X | X | 39,000 |
| | | | Total Cost of Plan | | | $3,539,000 |

damages or about $10,000 occurs to buildings. A high percentage of these buildings cannot be economically floodproofed because they are of wood frame construction and would require structural treatment. This alternative would not meet the present or future needs for development and utilization of the Deschutes Basin flood plain.

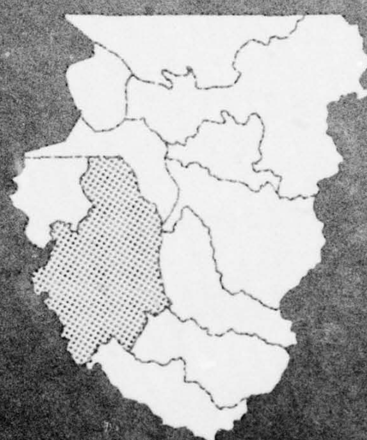
## Summary

Overbank flooding occurs on a frequency of about once every two years. Flooding damages agricultural lands, residences, urban and industrial developments, utilities and transportation facilities. Average annual flood damages are estimated to be $26,000 and the damage that would result from a flood with an estimated average recurrence interval of 100 years is estimated to be $340,000.

The trend of development in the basin is expected to result in future growths of flood damages approximating 2 percent compounded annually without flood control and could result in future growth of annual damages to $34,000 in 1980, $51,000 in 2000 and $76,000 in 2020.

Flood plain management should be initiated immediately to control developments in the flood plain. In the event that demand for more intensive use of flood plain lands occurs. Protection could be provided to individual portions of the flood plain by channelization and levee construction and to the entire flood plain by construction of upstream storage.

# West Sound Basins



# WEST SOUND BASINS

## DESCRIPTION OF BASINS

### GENERAL

The West Sound Basins, Figure 11-1, encompass about 2,620 square miles, including all of Kitsap County and portions of Jefferson, Clallam, Mason and Thurston Counties. The basins are bounded on the north by the Strait of Juan de Fuca, on the east by Puget Sound, on the south by the Chehalis River Basin, and on the west by the Olympic Mountains. Within these boundaries are the Kitsap Peninsula, Hood Canal, the eastern slopes of the Olympic Mountains, and numerous islands, channels, inlets and bays. Hood Canal is a long, narrow arm of Puget Sound about 1½ to 2 miles wide that extends along the foothills of the Olympic Mountains for 68 miles between the Olympic and Kitsap Peninsulas.

Because of the extreme difference in climate and topography, most of the streams on the Olympic Peninsula are large and swift, and those on the Kitsap Peninsula and the islands are small. The principal rivers on the eastern slopes of the Olympic Mountains are the Skokomish, Hamma Hamma, Duckabush, Dosewallips, Big Quilcene and Little Quilcene. All of these rivers head at elevations varying from 4,000 to 6,000 feet in the extremely rugged, forested Olympic National Park or Olympic National Forest and flow into Hood Canal. Profiles of these streams are shown on Figure 11-2.

The topography of the Kitsap Peninsula is generally flat, but includes undulating hills, ridges, low valleys and saltwater bays. Numerous islands range in size from less than a square mile to several hundred square miles. The Green Mountain–Gold Mountain area west of Bremerton rises above the surrounding plateau to an elevation of more than 1,700 feet above sea level. The peninsula is drained by 426 separate stream systems. Only 12 streams have drainage basins greater than 10 square miles. Most of these streams drain an area of less than a square mile.

The climate of the basins is characterized by relatively short, cool, dry summers and mild, wet winters. Mean annual precipitation ranges from about 220 inches at the headwaters of the Skokomish River in the southern portion to about 20 inches in the vicinity of Port Townsend at the northeastern tip of the Olympic Peninsula. The basins to the north and east have much lower precipitation because of the influence of the Olympic Mountains, which form a natural barrier to storms that sweep in from the Pacific Ocean.

### ECONOMY—PAST AND PRESENT

The Washington State Census Board estimated the 1967 population of the basins to be 124,000. The principal towns and their 1967 populations are: Bremerton, 36,000; the metropolitan area surrounding Bremerton, 30,000; Shelton, 6,230; Port Townsend, 5,430; Port Orchard, 3,850; Poulsbo, 1,730; and Winslow, 1,270. Most of the population and industrial development are in Kitsap County. The population of Kitsap County increased from 44,387 in 1940 to an estimated 96,683 in 1967. The increase from 84,176 in 1960 to 96,683 in 1967 represents an annual growth rate of about 1.4 percent. In comparison, the growth rate was 3.1 percent for the period 1940-1960, primarily as a result of the expansion of facilities at the Bremerton Naval Shipyard, the Keyport Naval Torpedo Station, and the Naval Ammunition Depot and Missile Facility at Bangor. These facilities make a major contribution to the economy of Kitsap County. Tables 11-1 and 11-2 contain information on population, employment and growth trends.

Activities in the forest industry range from a large pulp and paper mill at Port Townsend to Christmas tree farms near Shelton, the center of the logging industry.

Although of less importance than the naval facilities and the forest products industry, agriculture is important to the economy. Dairying, the raising of livestock and specialty crop farming are the principal agricultural pursuits. Numerous small dairy, poultry and berry farms occupy the uplands and creek valleys. Berry farming is an important growing industry on Bainbridge Island.

Olympia and Pacific oysters are cultivated and harvested in the tidewater inlets which lace the basin.

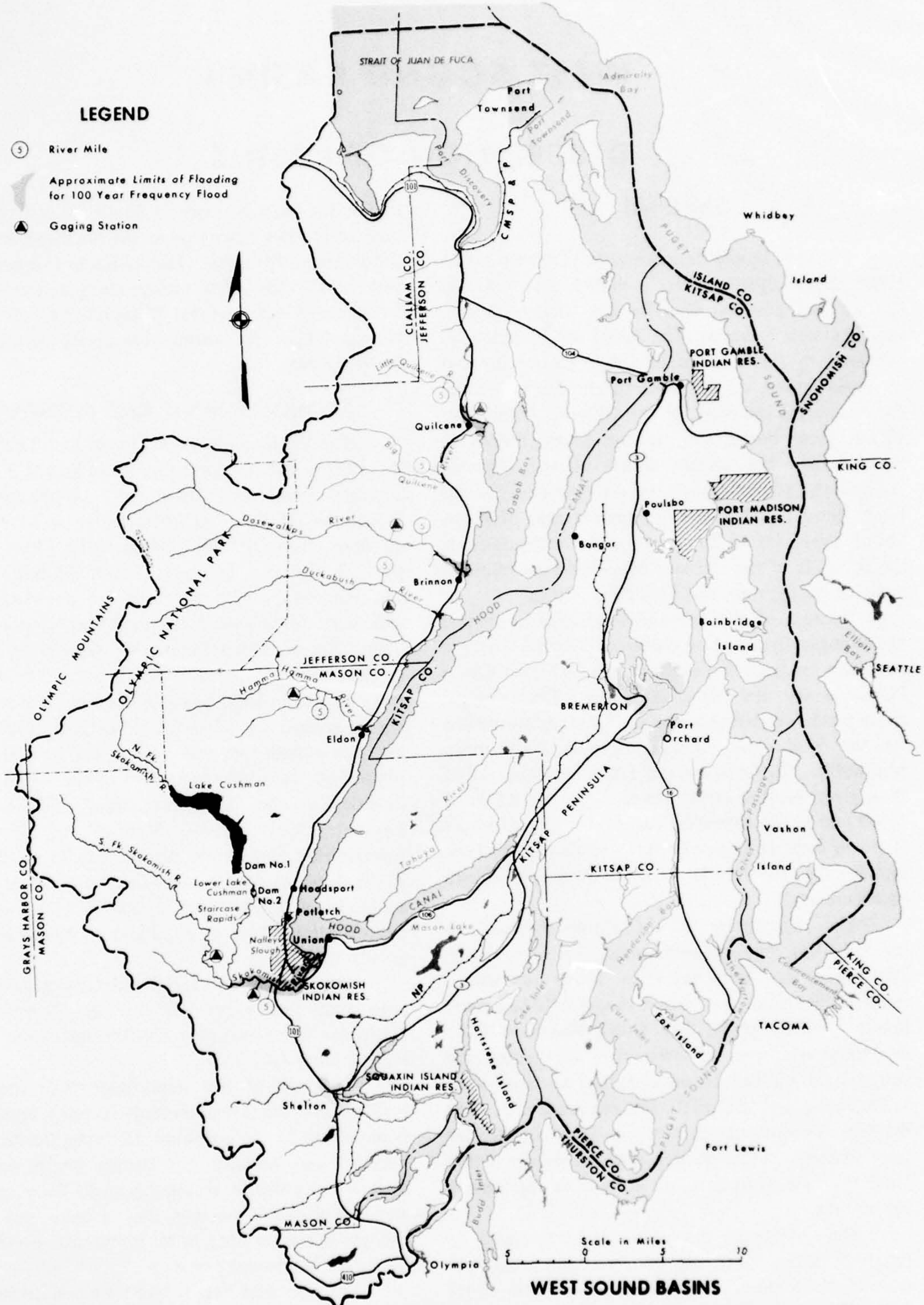
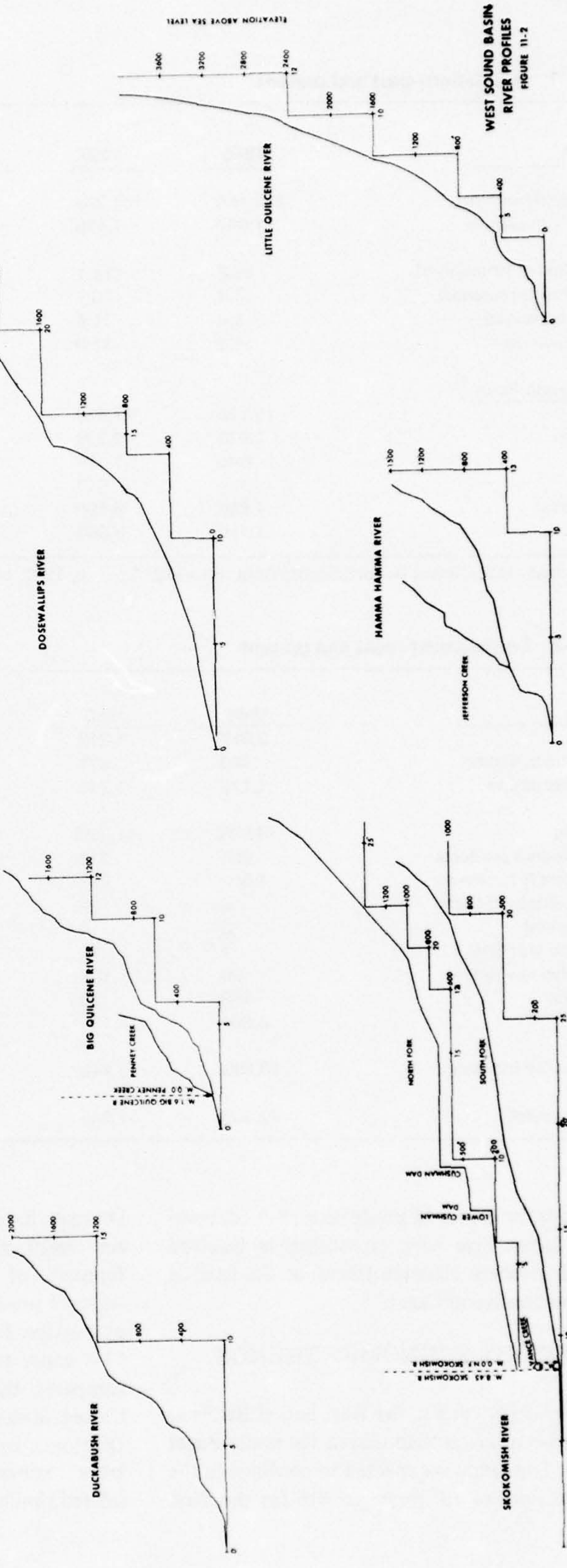



**FIGURE 11-1. Flood plain and existing protective works**




WEST SOUND BASIN
RIVER PROFILES
FIGURE 11-2

TABLE 11-1. Population—past and present

| Area | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| United States (thousands) | 132,164 | 151,326 | 179,323 | 200,100 | 52 |
| Puget Sound (thousands) | 1,007 | 1,418 | 1,768 | 2,100 | 105 |
| West Sound Basins (thousands) | 65.0 | 114.1 | 124.1 | 134.2 | 106 |
| Kitsap County (thousands) | 44.4 | 75.7 | 84.2 | 96.7 | 118 |
| Jefferson (thousands) | 9.0 | 11.6 | 9.6 | 10.0 | 11 |
| Mason (thousands) | 11.6 | 15.0 | 16.3 | 18.2 | 57 |
| Cities & Towns in Basin | | | | | |
| Bremerton | 15,130 | 27,680 | 28,920 | 36,170 | 139 |
| Port Orchard | 1,570 | 2,320 | 2,780 | 3,850 | 145 |
| Poulsbo | 640 | 1,010 | 1,500 | 1,730 | 170 |
| Winslow | -- | 640 | 920 | 1,270 | -- |
| Port Townsend | 4,680 | 6,890 | 5,080 | 5,430 | 16 |
| Shelton | 3,710 | 5,050 | 5,650 | 6,250 | 68 |

Figures are from U.S. Census Report, Seattle Area Industrial Council, 1967, and Appendix IV, Economics.

TABLE 11-2. Employment—past and present

| Industry | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| Agriculture | 2,017 | 1,818 | 786 | 670 | 66 |
| Forestry, Fishery, Mining | 460 | 871 | 679 | 550 | 20 |
| Contract Construction | 1,172 | 1,778 | 1,673 | 1,370 | 12 |
| Manufacturing | (8,665) | (11,629) | (14,348) | (15,890) | (83) |
| Food and kindred products | 235 | 278 | 349 | 140 | |
| Lumber, wood & furniture | 1,000 | 697 | -- | -- | |
| Chemical & allied products | 6 | 20 | 23 | 0 | |
| Fabricated metal | 3 | 4 | 13 | 0 | |
| Mach (Elec. & Non-Elec.) | 7 | 13 | 13 | 0 | |
| Transportation equipment | 50 | 187 | 217 | 0 | |
| Primary metal | 188 | 23 | 11 | 0 | |
| All other | 4,904 | 8,182 | 11,229 | 13,660 | |
| Non-Commodity Industry | 10,595 | 15,148 | 18,051 | 24,430 | 131 |
| Total Employment | 22,909 | 31,244 | 35,537 | 42,980 | 88 |

Totten Inlet is the center of production, but commercial oyster farms have been established in Oakland Bay, around northern Harstine Island, at the head of Case Inlet, and on Hood Canal.

## PROJECTED ECONOMIC TRENDS

Economic growth for the West Sound Basins in the past has been slower than that of the entire Puget Sound Area. This trend is expected to continue in the future. Projections of economic growth for the West Division have been made for the years 1980, 2000 and 2020 in Appendix IV. Table 11-3 contains a forecast of population, employment and gross regional product for the West Division and projects population for the West Sound River basins. Table 11-4 converts these forecasts into rates of growth and compares these rates to those projected for the United States. While the area contained by the West Division is not identical to the West Sound Basin area, gross regional product and employment are considered similar in each.

TABLE 11-3. Economic projections

| | 1963 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| West Division | | | | |
| Population (thousands) | 116.0 | 122.5 | 169.5 | 232.4 |
| Employment (thousands) | 37.7 | 41.9 | 57.6 | 79.5 |
| Gross Regional Product (Millions 1963 $) | 290.0 | 498.0 | 1,066.0 | 1,329.0 |
| West Sound Basins* | | | | |
| Population (thousands) | 124.2 | 175.0 | 274.1 | 432.7 |

* Contains the West Sound portion of Pierce County.

TABLE 11-4. Average annual growth trends (percent)

| | 1963 to 1980 | 1980 to 2000 | 2000 to 2020 | 1963 to 2020 |
|---|---|---|---|---|
| United States | | | | |
| Population | 1.3 | 1.3 | 1.3 | 1.3 |
| Employment | 1.6 | 1.4 | 1.3 | 1.5 |
| Gross National Product | 4.3 | 3.9 | 4.0 | 4.0 |
| West Division | | | | |
| Population | 0.3 | 1.7 | 1.6 | 1.2 |
| Employment | 0.6 | 1.6 | 1.6 | 1.3 |
| Gross Regional Product | 3.2 | 3.9 | 1.1 | 2.7 |
| West Sound Basins | | | | |
| Population | 2.0 | 2.3 | 2.3 | 2.2 |

The West Division is forecast to grow less rapidly than the Central or North divisions. In the 57-year period following 1963, the projected average annual growth is 1.2 percent for population, 1.3 percent for employment, and 2.7 percent for gross regional product. The major growth strength is drawn from the increasing number of tourists and recreationists that are attracted to the area. Scenic mountains, streams, lakes, and saltwater bays; hunting, fishing, beachcombing, and clamming opportunities; summer homes, camping, and picnicking are the main recreational attractions.

## LAND USE TRENDS

Tourism and outdoor recreation are assuming increasingly important roles. The construction of vacation homes, boating facilities, resorts and tourist accommodations is adding considerably to economic stability and growth. The trend in land use is towards an increase in retirement homes, summer homes and other recreational usage. Agricultural lands will become more intensively utilized as economics permit in areas with an adequate level of flood protection.

# SKOKOMISH RIVER BASIN

## PRESENT STATUS

### Stream System

The Skokomish River system drains an area of approximately 230 square miles, primarily in Mason County. The South Fork rises in the Olympic National Forest at elevation 4,000 feet and flows southeasterly for 25 miles. Vance Creek drains a relatively low area in the southern part of the basin and joins the South Fork about 500 feet upstream from the mouth of the North Fork. The North Fork originates from a small glacier at elevation 5,500 feet and flows southeasterly for 25 miles to the Skokomish River. The river flows northeasterly about 9 miles and discharges into the southern end of Hood Canal through two distributary channels. The Skokomish Valley has a maximum width of 15 miles. The gradients of the North and South Forks average about 100 feet a mile. Below their confluence with the Skokomish River, the gradient flattens abruptly to about 5 feet a mile, and the channel is braided and obstructed with gravel bars. The Skokomish is affected by tides for about 4 miles upstream from its mouth.

### Flood Plain

The 4,600-acre flood plain contains 1,550 acres of cultivated agricultural lands, 250 acres of improved roadways, and 2,800 acres of brush and woodlands. The flood plain has an average width of one mile, and extends upstream for approximately nine miles. The economy of the basin is based primarily on dairying and the raising of forage crops to support this industry. Soils are productive and would be suitable

for higher land use if relieved of the threat of flooding. The population of the Skokomish Basin is estimated to be 1,200. Most of the population is centered in the lower valley. Approximately 500 reside on the Skokomish Indian Reservation on the left bank of the river. There are no incorporated communities in the basin. Large scale logging operations are carried on in forested areas. U.S. Highway 101 and State Highway 106 cross the basin near the mouth of the river, and an improved farm-to-market road serves the valley.

## History of Flooding

**Flood Characteristics.** Floods in the Skokomish Basin usually coincide with periods of severe rainfall during the winter. Floodflows are characterized by a rapid rise from a comparatively low base flow to a peak discharge within a few hours, followed by a recession to base flow within 2 or 3 days. Several peaks are experienced each year, often in close succession. Figure 11-3 is a daily discharge hydrograph for the South Fork.

**Floods.** High flows have been recorded on the North Fork since 1913, on the South Fork since 1932, and on the Skokomish River since 1943. Discharges of 13,000 cfs on the Skokomish and 11,000 cfs on the South Fork are considered to be zero damage flows. The zero damage flow for the Skokomish River has been exceeded at least 29 times since 1943, as shown in Table 11-5. However, Cushman Dam has partially regulated floodflows on the North Fork since 1926 and significantly reduced peak discharges in the lower valley.

**TABLE 11-5. Peak discharges greater than zero damage (13,000 cfs at Potlatch Gage)**

| Date | Discharge cfs | Date | Discharge cfs |
|---|---|---|---|
| 7 Feb 1945 | 16,700 | 3 Nov 1955 | 27,000 |
| 14 Feb 1947 | 14,100 | 9 Dec 1956 | 17,200 |
| 19 Oct 1947 | 15,100 | 24 Feb 1957 | 15,100 |
| 27 Nov 1949 | 21,400 | 26 Feb 1957 | 14,600 |
| 2 Dec 1949 | 14,300 | 30 Apr 1959 | 23,600 |
| 28 Dec 1949 | 15,300 | 20 Nov 1959 | 22,100 |
| 26 Feb 1950 | 14,300 | 23 Nov 1959 | 16,200 |
| 3 Mar 1950 | 13,200 | 29 Jan 1960 | 14,400 |
| 10 Feb 1951 | 19,200 | 15 Jan 1961 | 26,400 |
| 3 Jan 1953 | 15,500 | 21 Feb 1961 | 15,000 |
| 12 Dec 1953 | 13,000 | 20 Nov 1962 | 18,300 |
| 5 Jan 1954 | 15,000 | 25 Nov 1962 | 15,700 |
| 19 Feb 1954 | 13,600 | 30 Nov 1964 | 15,600 |
| 18 Nov 1954 | 20,000 | 13 Jan 1966 | 14,800 |
| 7 Feb 1955 | 13,400 | | |

Discharges greater than 17,000 cfs result in major damage. Table 11-6 lists some recent major discharges, probable recurrence intervals and estimated damages.

**TABLE 11-6. Major floods and estimated damages**

| Date or Frequency | Peak Discharge at Potlatch Gage (cfs) | Average Recurrence Interval (years) | Current Estimated Damages |
|---|---|---|---|
| 3 Nov 1955 | 27,000 | 22 | $125,000 |
| 15 Jan 1961 | 26,400 | 20 | 114,000 |
| 30 Apr 1959 | 23,600 | 11 | 71,000 |
| 20 Nov 1959 | 22,100 | 8 | 56,000 |
| 50 year flood | 30,500 | 50 | 191,000 |
| 100 year flood | 34,000 | 100 | 266,000 |

Figures 11-4 and 11-5 show the estimated probability of annual maximum flows for the South Fork near Union and the Skokomish River at Potlatch.

**Flood Damages.** Average annual flood damages are estimated to be $27,000 at 1966 prices and conditions. Damages result largely to agricultural lands, crops, farm buildings and equipment, and fences. Table 11-7 tabulates flood damages by the general categories described in the Puget Sound Area Section of this appendix and the percentage of total damage in each category from major flood discharges.

**TABLE 11-7. Flood damage distribution—Skokomish River**

| Category | Percent of Total Damages |
|---|---|
| Agricultural | 33 |
| Buildings and equipment | 53 |
| Transportation facilities | 5 |
| Other | 9 |
| TOTAL losses and damages | 100 |

## Existing Flood Control Measures

### Flood Protective Works.

**Bank Protection and Stabilization.** Improvements by local interests, aided by the Public Works Administration and the Works Progress Administration, have been directed largely toward the prevention of bank erosion. Bank protective works constructed prior to 1936 along the right bank of the

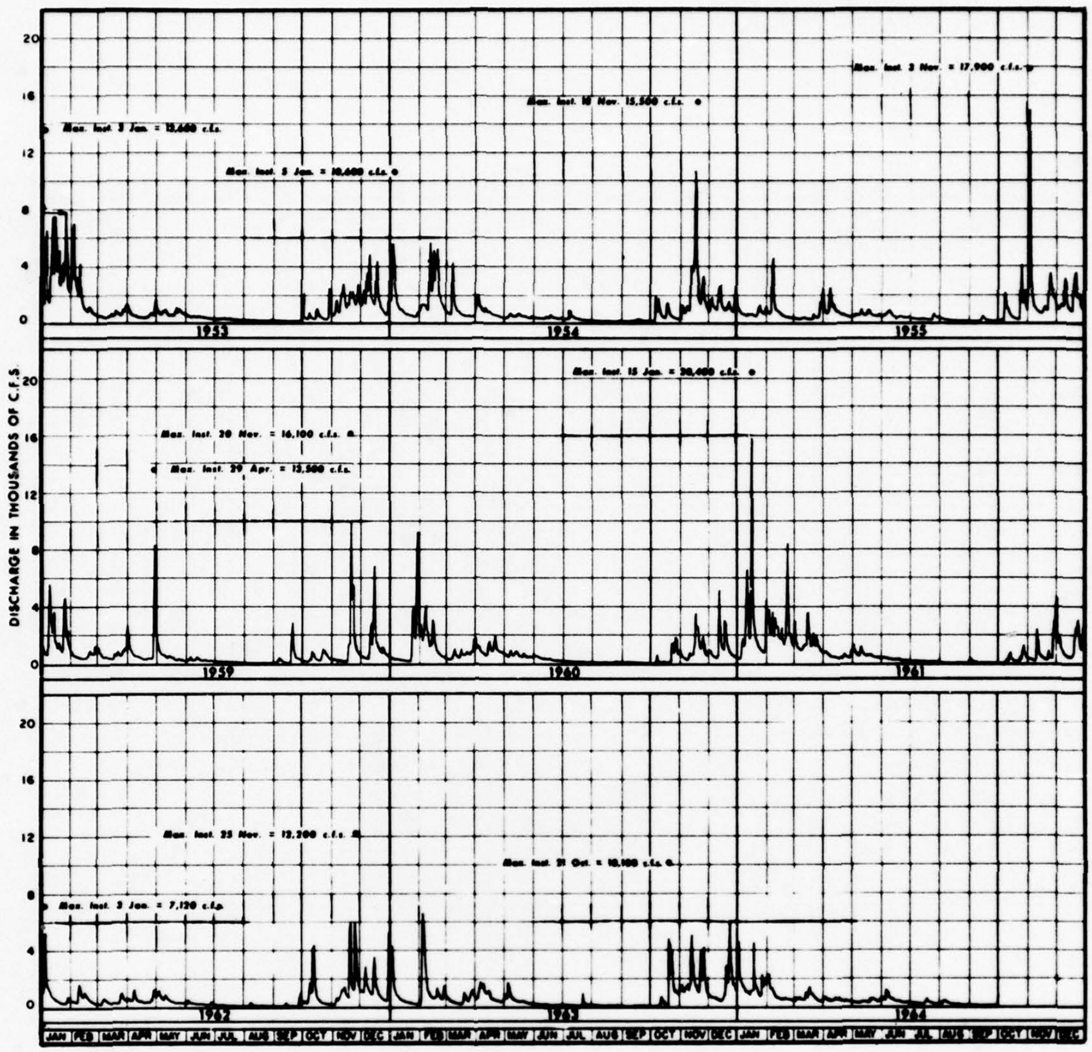



**FIGURE 11-3. Daily discharge hydrograph, South Fork Skokomish River near Union.**

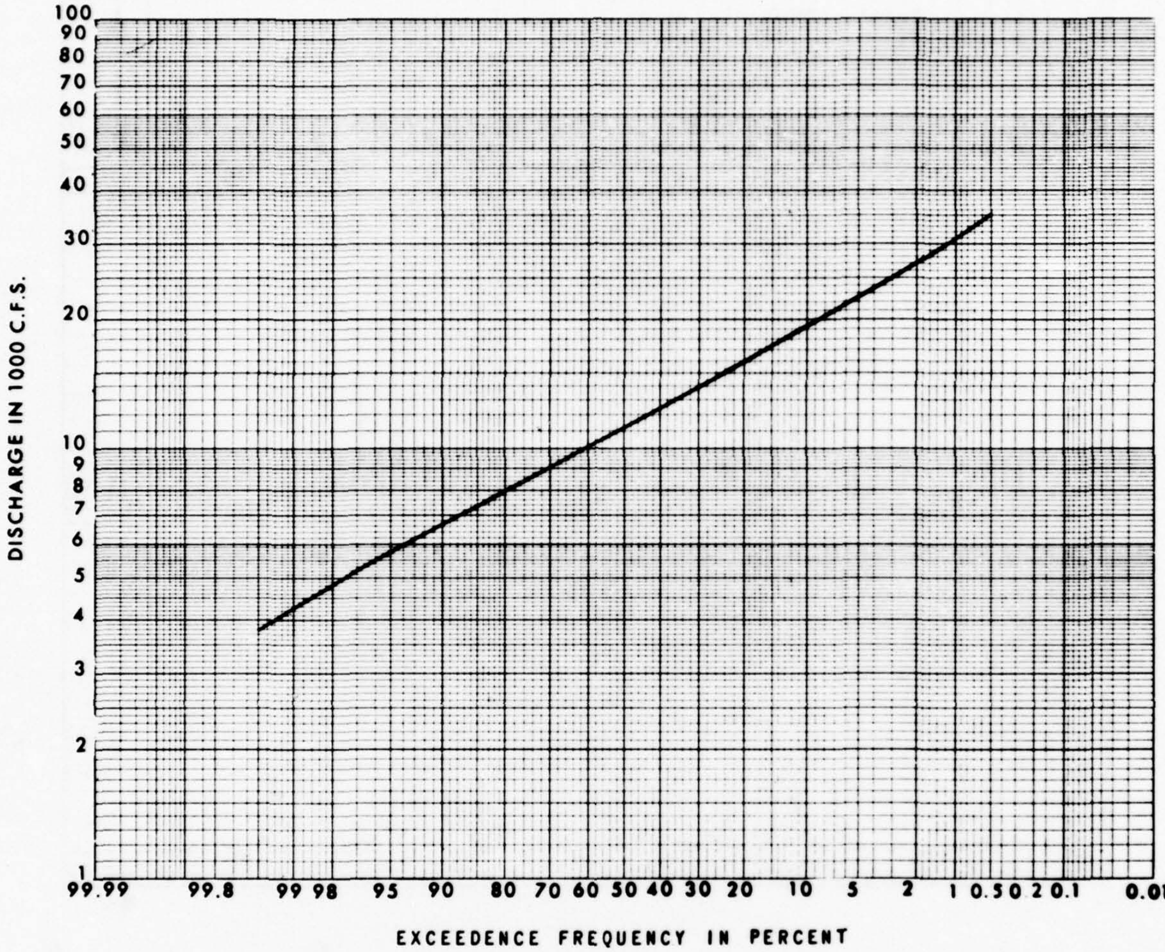



**FIGURE 11-4. Frequency curve of annual maximum peak flows, South Fork Skokomish River near Union**

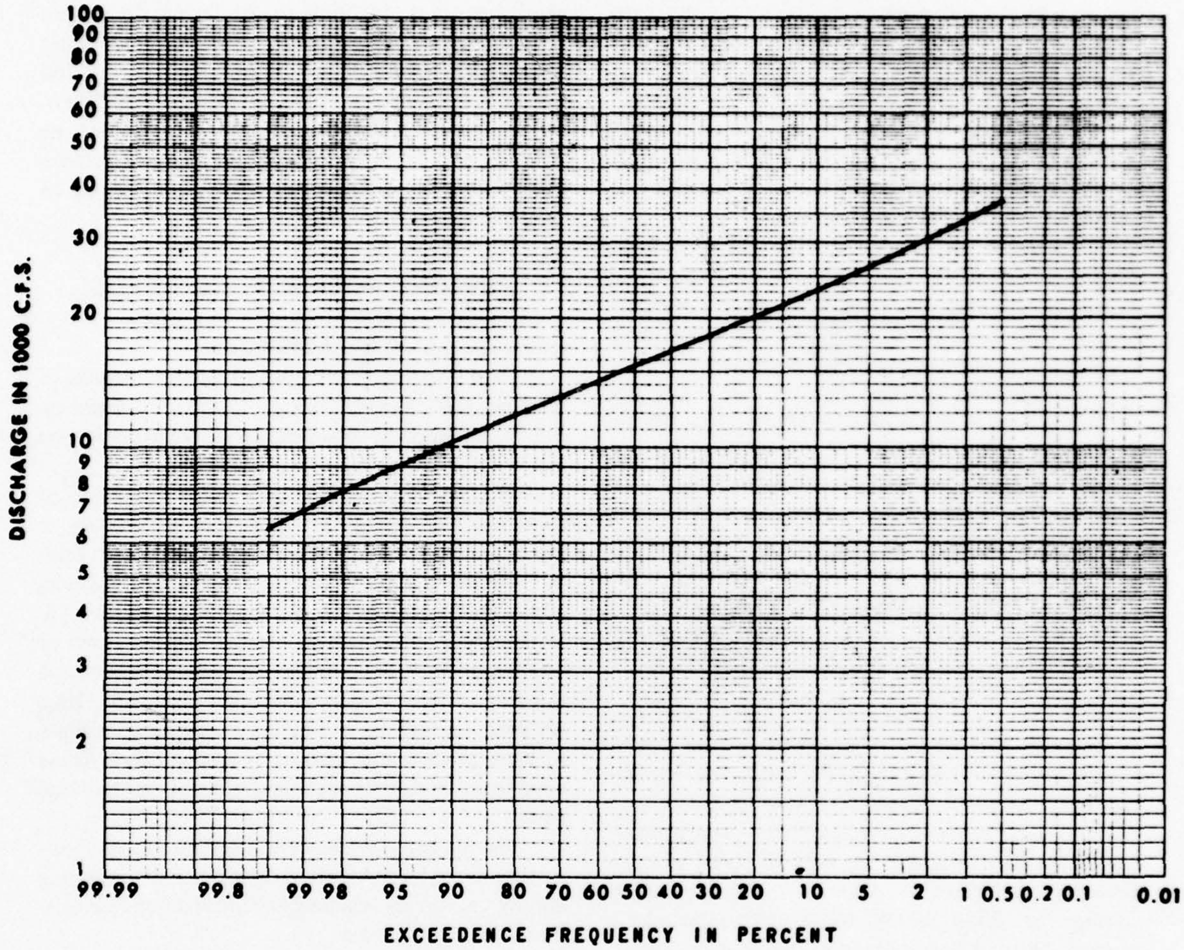



FIGURE 11-5. Frequency curve of annual maximum peak flows, Skokomish River near Potlatch

Skokomish River at various points consisted of training levees and revetments. In 1936 and 1937, the Works Progress Administration placed four log-floated shear cables, totaling 7,900 feet in length, across the bends where most of the erosion was taking place, and cleared the old channel bed along the northern bank opposite the cables. The purpose of the cables was to catch debris and divert the stream into the cleared channel. In 1940, local interests extended and strengthened one shear cable and improved the lower portion of the Vance Creek channel. The shear cables have provided some small local benefits, but have not accomplished their primary purpose.

**Levees.** A landowner has diked a large portion of the island between the two channels at the mouth of the river and some land west of Nalley's Slough. This land was formerly subject to frequent inundation by high tides and high riverflows.

**Upstream Storage.** Tacoma City Light has constructed two dams on the North Fork of the Skokomish River and operates two hydroelectric plants that have a combined maximum head of 735 feet. Cushman Dam No. 1 is approximately 9 miles above the mouth of the North Fork. The reservoir, Lake Cushman, is 9.6 miles long, covers 4,200 acres, and has a usable storage capacity of 360,000 acre-feet. Cushman Dam No. 2 is a reregulating project approximately 6 miles above the mouth of the North Fork with a reservoir 2 miles long. The reservoir has a storage capacity of 8,000 acre-feet. A tunnel 17 feet in diameter and 2.5 miles long leads to the powerhouse on Hood Canal near Potlatch. The Federal Power Commission license for these reservoirs does not provide for formal flood control storage; however, Tacoma City Light has held the level of Lake Cushman about 10 feet below the spillway elevation during the flood season to provide some flood storage. This voluntary action has reduced the magnitude of floodflows in the Skokomish Valley.

In 1931, Tacoma City Light obtained a preliminary permit from the Federal Power Commission for a proposed power project on the South Fork. Application for a license was filed on 7 September 1954. The city proposed to increase the power output of Cushman Plants 1 and 2 by diverting water from the South Fork reservoir through a tunnel to Lake Cushman. This proposed project would have a total storage capacity of 225,000 acre-feet. Application was filed on 8 July 1963 by the city of Tacoma to withdraw its application for license. Permission was greanted by the Federal Power Commission on 27 August 1963.

### Flood Problems

Swift tributary streams deposit large quantities of gravel and debris in the Skokomish River. High velocity flows for several miles downstream from the mouths of the tributaries causes the formation of debris jams that contribute to erosion and flooding in the flood plain almost every winter. Flood damages occur to agricultural land and to farm buildings and equipment. Based on 1966 prices and conditions, average annual flood damages are estimated to be $27,000, and damages from a flood with a recurrence interval of once in 100 years are estimated to be $51,000.

## PRESENT AND FUTURE NEEDS

### Evaluation of Present Situation

The existing flood control system consists of informal flood control storage in Lake Cushman on the North Fork Skokomish River, bank protection and stabilization projects, and low levees.

The informal flood storage in Lake Cushman of approximately 40,000 acre-feet provides control of low and moderate flood discharges on the North Fork of Skokomish River. However, this storage is inadequate to control major discharges. These flows, in combination with the uncontrolled natural flows of the South Fork Skokomish and Vance Creek, cause flooding along the main river almost annually. High velocity streamflows and a heavy bedload contribute to bank erosion and increase overbank flows. These conditions tend to restrict developments in the flood plain.

Bank protection and stabilization projects vary in standard of construction. Many are deteriorating rapidly and unless repaired or reinforced their effectiveness soon will be lost.

Low levees along the lower reaches of the river protect portions of this area from moderate floods and high tides but are inadequate for protection against major flood discharges.

### Flood Control Needs

**Prevention of Flood Damages.** Average annual damages are estimated to be $27,000 to agricultural lands, buildings and improvements, and transportation system facilities. Damage that would result from a flood with an estimated frequency of 100 years is estimated to be $51,000.

Based on the methodology and considerations previously discussed for the Puget Sound Area,

anticipated flood damages in the flood plains of the Skokomish River Basin are expected to increase by the percentages as shown in Table 11-8.

**TABLE 11-8. Percentage increases in productivity levels and developments for specified periods**

| Category of Damage | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Agriculture | 18 | 26 | 26 |
| Non-Agriculture | 35 | 55 | 55 |

Application of these percentages to the average annual damages based on 1966 prices and conditions provides an indication of future damages at 1966 prices if additional flood protection is not provided. Table 11-9 shows that the combination of all categories of damage are expected to increase from about $27,000 in 1966 to $76,000 by the year 2020.

**TABLE 11-9. Existing and Future Annual Damages (in thousands of dollars)**

| | Under Development Levels of | | | |
|---|---|---|---|---|
| Category | 1966 | 1980 | 2000 | 2020 |
| Agriculture | 9 | 10 | 13 | 17 |
| Buildings & equipment | 14 | 19 | 30 | 46 |
| Other | 4 | 5 | 8 | 13 |
| TOTAL | 27 | 34 | 51 | 76 |

**Optimum Flood Plain Use.** The flood plain of the Skokomish River is expected to remain predominantly in agricultural use. Agricultural use may change from dairying and beef production to berry and vegetable production in areas where adequate flood protection is provided. Additional recreational developments including camping, picnicking, and vacation homes can be expected within the flood plain area.

## Summary of Flood Control Needs

There is a need to reduce the present average annual flood damages of $27,000 that occurs to developments and equipment, agricultural lands, and transportation facilities. The trend of development in the basin is expected to result in the future growth of flood damages approximating 2 percent compounded annually if additional flood control is not provided. Future growth of average annual flood damages are expected to be $34,000 in 1980, $51,000 in 2000, and $76,000 in 2020.

Additional flood control is needed to permit intensive agricultural and recreational developments on the Skokomish valley flood plain. Bank protective works will be required if severe bank erosion is to be prevented along the lower reaches of the river. Structural flood control measures should be provided to the maximum extent that the economy will permit; and land areas should be managed to insure development is commensurate with the flood protection provided.

# *MEANS TO SATISFY NEEDS*

## Flood Control Objectives

The flood control objectives are to meet the needs set forth in the preceding section by providing flood control through utilization of both structural and non-structural measures. Objectives of structural measures are to provide a 25-year level of flood protection to agricultural lands to permit increased agricultural returns. Non-structural measures would include flood plain management consistent with the flood protection provided.

## Opportunities for Structural Measures

**Upstream Storage.** The existing Cushman Reservoirs No. 1 and No. 2 on the North Fork of the Skokomish River and the diversion of flow to the Tacoma City Light powerhouse at Potlatch has appreciably reduced peak flood discharges on this tributary. An agreement for formal flood control storage at these projects may be possible.

A suitable storage site exists on the South Fork of the Skokomish River. An estimated 60,000 acre-feet of flood control storage in combination with 42,000 acre-feet of storage on the North Fork would control a flood with an average estimated recurrence interval of 100 years to zero damage flow.

**Levees.** Levees along 7 miles on the right bank and 4 miles on the left bank of the river would provide protection to approximately 3,000 acres. Maintenance costs of such a levee system would be high due to the excessive debris deposits during flood periods.

**Bank Protection.** Bank erosion during the past 30 years has occurred at approximately six locations having a total length of 7,600 feet, and has resulted in the loss of approximately 40 acres of land. Prevention

of erosion in these areas would involve revetment of about 10,000 linear feet of streambank.

## Solutions to Flood Control Needs

**General.** Features of the flood control plan are detailed in Table 11-10 and shown on Figure 11-6. Flood plain management is the nucleus of the flood control plan for the Skokomish River Basin. However, if sufficient demand is made for more intensive use of the flood plain in the future, flood plain management will have to be supplemented by levee and channel improvements to provide the degree of protection required.

**Sequence of Development.**

**To 1980.** Flood plain management should be implemented to insure that flood plain developments are commensurate with the degree of flood protection provided.

**TABLE 11-10. Flood control plan—Skokomish River Basin**

| Flood Control Feature | Sequence of Development to 1980 | to 2000 | to 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|
| Flood Plain Management | X | X | X | $ 16,000 |
| Levee Construction —River Mile 0.0 to River Mile 10 | | | X | $900,000 |
| TOTAL cost of plan | | | | $916,000 |

**1980-2020.** When the demand for intensive use of the flood plain occurs, additional flood protection could be provided by levee and channel improvements. Flood plain management will be continued.

**Accomplishments.** The accomplishments of the flood control plan prior to 1980 would be to control the developments on flood plain lands. Construction of levees and channel improvements or upstream storage could provide the entire 4,600-acre flood plain with protection adequate for intensive development.

***Alternatives Considered.*** Single-purpose flood control storage cannot be economically justified in the forseeable future. Annual costs as shown in Table 11-11 include interest and amortization of the total investment (including interest during construction), average annual costs of operation and the equivalent average annual cost of major replacements. An economic life of 100 years was used for storage projects and 50 years for levee and bank protective works. An interest rate of 4-5/8 percent was used to compute interest during construction, the present worth of future costs, and amortized annual costs.

The annual cost of providing protection by levees is estimated to be almost four times the resulting benefits and so cannot be justified prior to 1980. The annual cost of preventing bank erosion is estimated to be more than 10 times the estimated annual benefits.

Flood plain management and flood proofing of existing buildings was evaluated as an alternative to major flood protective works for reduction of present and future flood damages. Approximately 50 percent

**TABLE 11-11. Costs and benefits of alternative flood control measures**

| Flood Control Features | Effective Flood Control Storage Acre-feet | Design Capacity cfs | Estimated Development Costs Based on 1968 Costs | Estimated Annual Cost | Est. Annual Flood Damage Prevention Benefits 1966 Prices |
|---|---|---|---|---|---|
| Storage | | | | | |
| South Fork Skokomish Site | 60,000 | | $22,500,000 | $1,100,000 | $25,000 |
| Levees | | | | | |
| River Mile 0.0 to River Mile 10 | | 29,000 | 900,000 | $ 100,000 | 25,000 |
| Bank Protection | | | | | |
| River Mile 0.0 to River mile .0 | | -- | 300,000 | $ 17,000 | 1,200 |

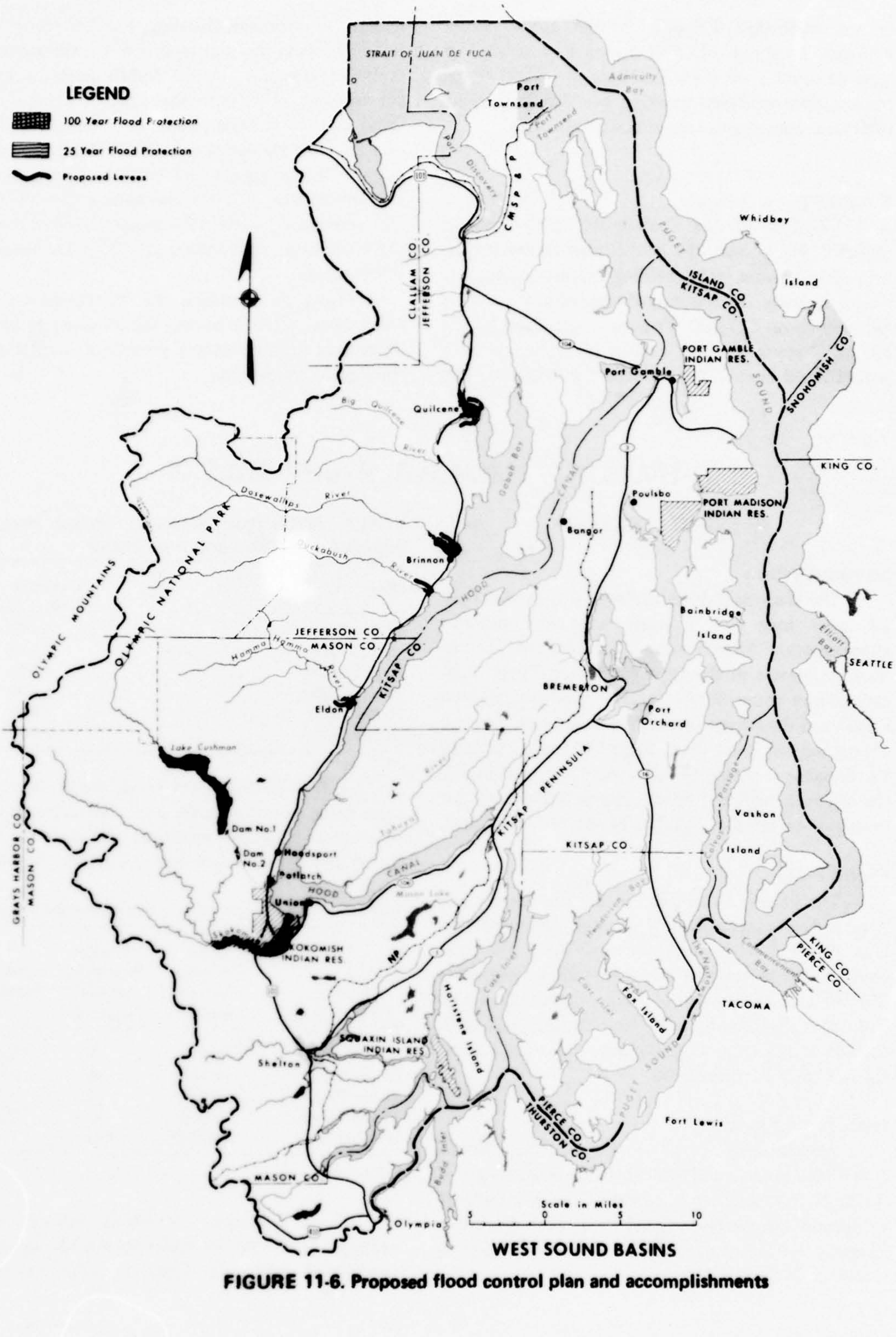



**FIGURE 11-6. Proposed flood control plan and accomplishments**

of the estimated $27,000 average annual flood damages, or about $13,500 occurs to buildings. A high percentage of these buildings are wood frame construction and flood proofing would require structural treatment that is economically infeasible.

### Summary

Flooding of the Skokomish Valley lands is frequent, but because the land is used almost exclusively for pasture and flooding occurs during the winter months, the resulting average annual damages are only about $27,000. Voluntary operation by the city of Tacoma of the Cushman No. 1 reservoir for partial flood control has reduced the frequency and severity of overbank flooding. Further reduction in flooding could be accomplished by storage in the proposed reservoir on the South Fork or by the construction of levees. The cost of single-purpose flood control storage cannot be economically justified but this storage should be included as a project purpose in any future multipurpose storage project. The annual cost of levees and bank protective works also excessively exceeds the annual overflow damages and their construction prior to 1980 is not economically feasible.

Flood plain zoning and management of the entire flood plain to control future development and to prevent future excessive growth of flood damages should be implemented.

# HAMMA HAMMA RIVER BASIN

## PRESENT STATUS

### Stream System

The Hamma Hamma drainage is approximately 12 miles long and 9 miles wide and contains approximately 55,000 acres. The Hamma Hamma River originates in the Olympic National Park at an elevation of about 6,000 feet, flows easterly to Hood Canal, and discharges through two channels. Average annual rainfall varies from 70 to 140 inches. Most of the drainage is within the Olympic National Park and the Olympic National Forest. About 1,200 acres are in private ownership, mostly adjacent to Hood Canal.

### Flood Plain

The 66-acre flood plain of the Hamma Hamma River extends approximately one mile upstream from U.S. Highway 101. Improvements along the right bank include several vacation cabins and a dairy farm. This 30-acre area consists of 3 acres of cultivated land and about 26 acres of pastureland. Unimproved roads provide access from U.S. Highway 101. Land along the left bank is undeveloped.

### History of Flooding

**Floods.** High flows of the Hamma Hamma River have been recorded since 1951. A discharge of 4,100 cfs measured at the Eldon Gage is considered to be zero damage flow. Since 1951, peak discharges have exceeded zero damage flow at least six times, as shown in Table 11-12.

**TABLE 11-12. Peak discharges greater than zero damage (4,100 cfs at gage near Eldon)**

| Date | Discharge cfs |
|---|---|
| 19 Nov 1954 | 4,280 |
| 3 Nov 1955 | 5,810 |
| 24 Feb 1958 | 4,440 |
| 29 Jan 1960 | 5,410 |
| 15 Jan 1961 | 4,920 |
| 4 Feb 1963 | 4,340 |

A flow of 6,400 cfs would cause major damages. Table 11-13 gives the peak discharges, probable recurrence intervals, estimated damages of major floods and the estimated 50 and 100-year floodflows.

**TABLE 11-13. Major floods and estimated damages**

| Date or Frequency | Peak Discharge at Eldon Gage (cfs) | Average Recurrence Interval (years) | Current Estimated Damages |
|---|---|---|---|
| 3 Nov 1955 | 5,810 | 7 | $1,600 |
| 29 Jan 1960 | 5,410 | 6 | 1,100 |
| 15 Jan 1961 | 4,920 | 5 | 1,000 |
| 50-year flood | 9,900* | 50 | 7,200 |
| 100-year flood | 11,600* | 100 | 7,900 |

* Estimated

**Flood Damages.** Estimated average annual damages, primarily to flood protective works and agricultural land, are $800 at 1966 prices and

conditions. Table 11-14 tabulates flood damages by the general damage categories described in the Puget Sound Area Section of this appendix and the percentage of total damage that would result in each category from major floods.

**TABLE 11-14. Flood damage distribution—Hamma Hamma River**

| Category | Percent of Total Damages |
|---|---|
| Diking system | 52 |
| Agricultural | 31 |
| Buildings and equipment | 14 |
| Other | 3 |
| TOTAL losses and damage | 100 |

### Existing Flood Control Measures

**Flood Protective Works.** A levee on the right bank, approximately 4,000 feet upstream from U.S. Highway 101, affords protection from minor floods. The levee is about 600 feet long and 6 feet high, has a 10-foot top width, and is partially faced with rock weighing less than 1,000 pounds. A training dike downstream from U.S. Highway 101 on the left bank protects oyster beds from floodflows.

### Flood Problems

Minor flooding begins with a dishcarge of 4,100 cfs and occurs about once every 3 years. Most of the flood plain would be inundated by a discharge of 6,400 cfs, a flow with an estimated recurrence interval of once in 17 years. Flood damage is minor because of limited development; however, the flood plain has an excellent recreational potential and flood damages can be expected to increase with additional development.

## PRESENT AND FUTURE NEEDS

### Evaluation of Present Situation

Development in the 66-acre flood plain consists of several vacation cabins and a small dairy farm occupying about 30 acres on the right bank of the Hamma Hamma River. U.S. Highway 101 crosses the lower delta. Flood protective works consist of a short levee and a training dike that provide adequate protection from minor floods for existing development. A flood of 6,400 cfs would overtop the levee and inundate most of the flood plain on an expected frequency of once in 17 years. The flood plain has an excellent recreational potential, and flood damages will increase if additional development occurs.

### Flood Control Needs

**Prevention of Flood Damages.** Average annual flood damages are estimated to be $800 and result from damages to flood protective works, agricultural lands, and buildings. Damages that would result from a storm with an expected recurrence interval of 100 years are estimated to be $7,900. Flood damages are not extensive under existing conditions.

Based on the methodology and considerations previously discussed for the Puget Sound Area, anticipated flood damages in the flood plains of the Hamma Hamma River Basin are expected to increase by the percentages as shown in Table 11-15.

**TABLE 11-15. Percentage increases in productivity levels and developments for specified periods**

| Category of Damage | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Agriculture | 18 | 26 | 26 |
| Non-Agriculture | 35 | 55 | 55 |

Application of these percentages to the average annual damages based on 1966 prices and conditions provides an indication of future damages at 1966 prices if additional flood protection is not provided. Table 11-16 shows that the combination of all categories of damage are expected to increase from about $800 in 1966 to $2100 by the year 2020.

**TABLE 11-16. Existing and future annual damages (in thousands of dollars)**

| Category | Under Development Levels of 1966 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Agriculture | 420 | 500 | 600 | 800 |
| Buildings and Equipment | 110 | 150 | 230 | 370 |
| Diking System | 250 | 340 | 530 | 860 |
| Other | 20 | 30 | 40 | 70 |
| TOTAL | 800 | 1,020 | 1,400 | 2,100 |

**Optimum Flood Plain Use.** The flood plain of the Hamma Hamma Basin has excellent potential for

additional recreational use, including summer homes, if adequate flood protection can be provided.

### Summary of Flood Control Needs

The average annual flood damages of $800 under 1966 conditions are not excessive due to the limited developments on the Hamma Hamma River flood plain. This flood plain, however, has excellent potential for recreational development and future flood damages can be expected to increase if development occurs without adequate flood protection.

## MEANS TO SATISFY NEEDS

### Flood Control Objectives

The flood control objectives are to reduce existing and future flood damages and permit optimum use of the flood plain by both structural and non-structural methods consistent with economic justification. Non-structural measures would include flood plain management consistent with the flood protection provided.

### Opportunities for Structural Measures

**Upstream Storage.** Suitable upstream storage sites exist on the Hamma Hamma River. Costs for developing this storage as single-purpose projects were not estimated because of the obviously low resulting benefit-cost ratios.

**Levees.** A levee approximately one mile long on the right river bank of the delta area could protect the major portion of the flood plain.

### Solutions to Flood Control Needs

**General.** Features of the flood control plan are detailed in Table 11-17 and Figure 11-6. Flood plain management is the nucleus of the flood control plan for the basin. In the event that vacation homes are constructed in the flood plain, adequate flood protection should be provided.

**Sequence of Development**

**To 1980.** Flood plain management should be implemented to prevent encroachment of developments onto flood plain lands which are not compatible with the degree of flood protection provided.

**1980-2020.** When the demand for intensive use of the flood plain is such that more flood protection should be provided, flood plain management could be supplemented with construction of levees.

**TABLE 11-17. Flood control plan, Hamma Hamma River Basin**

| Flood Control Feature | Sequence of Development to 1980 | to 2000 | to 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|
| Levees | | | X | $180,000 |
| Flood Plain Management | X | X | X | 11,000 |
| TOTAL COST OF PLAN | | | | $191,000 |

**Economic Analysis.** The cost of constructing a levee system is estimated to be $180,000 based on 1966 prices. Annual costs were computed using 4-5/8 percent interest, a 50-year project life, and average annual cost of maintenance. These annual costs are estimated to be $14,000 and as they exceed the average annual overflow damages of $800 by many times, construction of this levee in the foreseeable future would not be economically feasible.

**Accomplishments.** Flood plain management would control the development of flood plain lands until adequate protection can be provided. Construction of the levee system could provide the entire 66-acre flood plain with protection adequate for intensive land use.

**Alternatives Considered.** Upstream storage was considered as an alternative flood control measure; however, the cost of providing this storage would be much greater than levee construction.

Flood proofing of existing buildings was evaluated as an alternative to major flood protective works for reduction of present and future flood damages. Approximately 10 percent of the estimated $800 average annual flood damage, or about $80, occurs to buildings. Flood proofing has limited application and should be utilized to the extent feasible. This alternative however, will not appreciably reduce the present damages or permit intensive development of the flood plain in the future.

### Summary

Minor flooding occurs on the 66-acre flood plain about once every three years and most of the flood plain would be inundated by a flow with an estimated average recurrence interval of once in 17 years.

Average annual flood damages are estimated to

be $800. Reduction in flood damages could be accomplished by levee construction but the annual costs would exceed the amount of flood control benefits by many times. Flood plain management should be initiated immediately because the flood plain has an excellent recreational potential and flood damages can be expected to increase in proportion to future additional developments.

# DUCKABUSH RIVER BASIN

## PRESENT STATUS

### Stream System

The Duckabush River drainage is approximately 20 miles long in an east-west direction and has a maximum width of about 10 miles. The Duckabush River originates in the Olympic National Park above elevation 6,000 feet. Precipitation varies from 50 to 200 inches per year. Most of the drainage is within the Olympic National Park and the Olympic National Forest. Hydrologic cover is good.

### Flood Plain

The delta contains a 70-acre flood plain upstream from U.S. Highway 101. The lower one mile has been subdivided into approximately 200 summer home plots. A few homes have been constructed and others are under construction. Some of the lots are occupied by small house trailers during the summer. The structures shown in photographs 11-1 and 11-2 are typical of the developments in the flood plain.

### History of Flooding

**Floods.** High flows on the Duckabush River have been recorded since 1938. A discharge of 4,200 cfs measured at the gage near Brinnon is considered to be zero damage flow. Since 1938, peak discharges have exceeded zero damage flow at least 26 times, as shown in Table 11-18.

A flow exceeding 7,000 cfs will cause major damage, and has occurred once during the period of record.

Table 11-19 gives discharges and their probable recurrence intervals and the estimated discharge of a 100-year floodflow. Estimated damages are based on 1966 prices and conditions.

Figure 11-7 shows the estimated probability of annual maximum floods for the Duckabush River.

PHOTO 11-1. Typical summer home development on left bank near mouth of Duckabush River. Notice the high water mark from the December 1966 flood on the door of the building.

PHOTO 11-2. Covered picnic shelter on right bank near mouth of Duckabush River. 1 December 1966 floodwater was about 0.1 foot above concrete floor. Corps of Engineers photo, 7 December 1966.

**TABLE 11-18. Peak discharges greater than zero damage (4,200 cfs at the gage near Brinnon)**

| Date | Discharge cfs | Date | Discharge cfs |
|---|---|---|---|
| *1 Jan 1939* | *4,960* | *9 Dec 1956* | *4,290* |
| 7, 8 Dec 1939 | 5,940 | 18 Feb 1948 | 4,249 |
| 15 Dec 1930 | 6,080 | 24 Feb 1958 | 4,910 |
| 2 Jan 1940 | 4,750 | 8 Jan 1959 | 4,750 |
| 23 Oct 1940 | 4,750 | 22 Nov 1959 | 4,690 |
| 13 Nov 1941 | 4,310 | 29 Jan 1960 | 6,500 |
| 2 Dec 1941 | 6,080 | 15 Jan 1961 | 5,280 |
| 7 Feb 1945 | 5,500 | 13 Oct 1962 | 4,720 |
| 12 Feb 1947 | 5,370 | 19 Nov 1962 | 5,980 |
| 19 Oct 1947 | 5,970 | 25 Nov 1962 | 4,500 |
| 26 Nov 1949 | 8,960 | 4 Feb 1963 | 5,810 |
| 19 Nov 1954 | 5,260 | 21 Oct 1963 | 4,980 |
| 3 Nov 1955 | 5,800 | 14 Nov 1963 | 4,680 |

**TABLE 11-19. Major floods and estimated damages**

| Date or Frequency | Peak Discharge at Brinnon Gage (cfs) | Average Recurrence Interval (years) | Current Estimated Damages |
|---|---|---|---|
| 26 Nov 1949 | 8,960 | 50 | $30,000 |
| 29 Jan 1960 | 6,500 | 8 | 6,000 |
| 2 Dec 1941 | 6,080 | 6 | 4,000 |
| 100-year flood | 10,000 | 100 | 49,400 |

**Flood Damages.** Average annual damages are estimated to be $3,000 at 1966 prices and conditions. Flood damage is sustained by summer homes and recreational facilities. Table 11-20 tabulates flood damages by the general damage categories described in the Puget Sound Area Section of this appendix and the percentage of the total damage in each category.

**TABLE 11-20. Flood damage distribution-Duckabush River**

| Category | Percent of Total Damage |
|---|---|
| Buildings and Equipment | 94 |
| Other | 6 |
| Total losses and damages | 100 |

## Existing Flood Control Measures

No flood protective works have been constructed on the Duckabush River.

## Flood Problems

Overbank flooding occurs when discharges exceed 4,200 cfs, a flow with a recurrence interval of about once every two years. Several summer homes

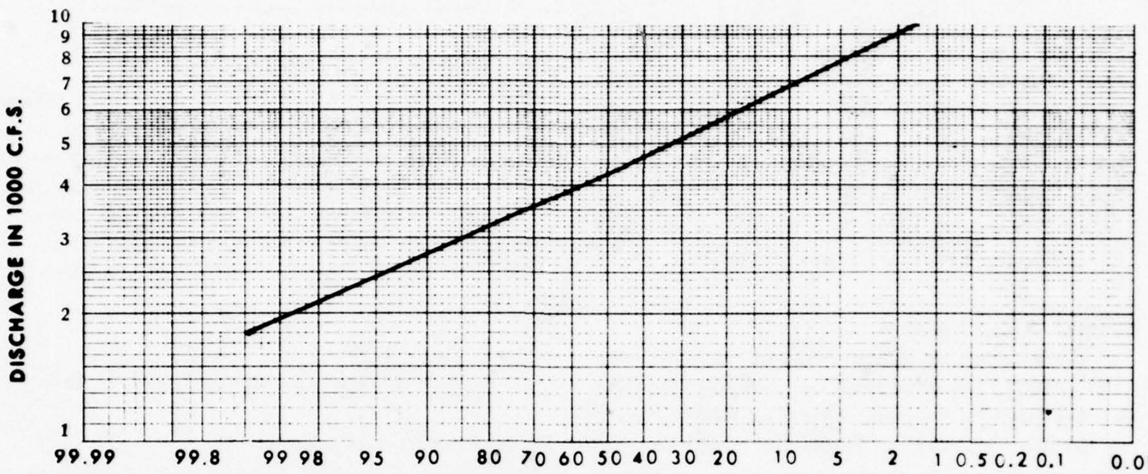



FIGURE 11-7. Frequency curve of annual maximum peak flows, Duckabush River near Brinnon

and a picnic area in the flood plain suffer minor damage. Vegetation on the streambanks has stabilized the channel and erosion is minor.

## PRESENT AND FUTURE NEEDS

### Evaluation of Present Situation

No flood protective works have been constructed along the Duckabush River. The 70-acre flood plain contains a subdivision with more than 200 summer home plots. A few homes have been built and others are under construction. Based on 1966 prices and conditions, estimated average annual flood damages are $3,000. The construction of additional summer homes is likely and flood damages will increase in proportion to the new development.

### Flood Control Needs

**Prevention of Flood Damages.** Based on the methodology and considerations previously discussed for the Puget Sound Area, anticipated flood damages in the flood plains of the Duckabush River Basin are expected to increase by the percentages as shown in Table 11-21.

**TABLE 11-21. Percentage increases in productivity levels and developments for specified periods**

| Category of Damage | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Buildings and Equipment | 35 | 55 | 55 |
| Non-Agriculture | 35 | 55 | 55 |

Application of these percentages to the average annual damages based on 1966 prices and conditions provides an indication of future damages at 1966 prices if additional flood protection is not provided. Table 11-22 shows that the combination of all categories of damage are expected to increase from about $3,000 in 1966 to $10,000 by the year 2020.

**Optimum Flood Plain Use.** The flood plain of the Duckabush River Basin has excellent potential for additional recreational and summer home development if adequate flood protection can be provided.

**TABLE 11-22. Existing and future annual damages (in thousands of dollars)**

| Category | Under Development Levels of 1966 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Buildings and equipment | 2,800 | 3,800 | 5,900 | 9,300 |
| Other | 200 | 300 | 400 | 700 |
| TOTAL | 3,000 | 4,100 | 6,300 | 10,000 |

### Summary of Flood Control Needs

The average annual flood damages of $3,000 under 1966 conditions are not excessive due to the limited amount of development. This flood plain, however, has excellent potential for future summer homes and recreational developments and future flood damages can be expected to increase if additional development occurs without adequate flood protection.

## MEANS TO SATISFY NEEDS

### Flood Control Objectives

The flood control objectives are to reduce existing and future flood damages and permit optimum use of the flood plain by both structural and non-structural methods consistent with economic justification. Non-structural measures would include flood plain management consistent with the flood protection provided.

### Opportunities for Structural Measures

**Upstream Storage.** Suitable upstream storage sites exist on the Duckabush River but single-purpose flood control development projects were not evaluated because of the small amount of existing flood damages.

**Levees.** A levee approximately 2,500 feet long on the right riverbank and 3,500 long on the left riverbank could provide 50-year protection to summer homes and recreational facilities.

### Solutions to Flood Control Needs

**General.** Features of the flood control plan are detailed in Table 11-23 and shown on Figure 11-6. Flood plain management is the nucleus of the flood control plan for the basin. However, in the event that the flood plain is utilized for summer homes and recreational facilities additional protection can be provided by construction of levees.

**TABLE 11-23. Flood control plan, Duckabush River Basin**

| Flood Control Feature | Sequence of Development to 1980 | to 2000 | to 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|
| Levees | | | X | $220,000 |
| Flood Plain Management | X | X | X | 11,000 |
| TOTAL COST OF PLAN | | | | $231,000 |

**Sequence of Development**

**To 1980.** Flood plain management should be implemented to insure that development of flood plain lands is consistent with the degree of flood protection provided.

**1980-2020.** In the event that intensive use of the flood plain is required adequate protection could be provided by levees.

**Economic Analysis.** The cost of providing a levee system is estimated to be $220,000 based on 1966 prices. Annual costs were computed using 4-5/8 percent interest, a 50-year project life and the average annual cost of maintenance. The annual costs are estimated to be $20,000 and greatly exceed the estimated annual flood damages of $3,000. Construction of this levee system will not be economically feasible in the foreseeable future.

**Accomplishments.** Flood plain regulations should insure that developments are consistent with the flood hazard. Construction of the levee system would provide the entire 70-acre flood plain with adequate protection for intensive land use.

**Alternatives Considered.** Upstream storage was considered as an alternative flood control measure; however, the cost of providing this storage would be excessive.

Flood proofing of existing buildings was evaluated as an alternative to major flood protective works for reduction of present and future flood damages. Approximately 90 percent of the estimated $3,000 average annual flood damages, or about $2,700, occurs to buildings. These buildings, however, are of wood frame construction and flood proofing would not be economically feasible.

## Summary

Overbank flooding occurs on a frequency of about once every two years. Average annual flood damages are estimated to be $3,000 and the damages that would occur from a flood with an average recurrence interval of 100 years is estimated to be $49,400 based on 1966 prices and conditions. Reduction in flood damages could be accomplished by levee construction but the annual costs of these protective works would greatly exceed the resulting flood benefits. Flood plain management should be initiated immediately to control recreational development of the flood plain.

# DOSEWALLIPS RIVER BASIN

## PRESENT STATUS

### *Stream System*

The Dosewallips River is formed by the confluence of Silt and West Creeks, which rise in the Olympic National Park. From its source, the river system flows about 30 miles in an easterly direction to Hood Canal and drains approximately 117 square miles. Most of the watershed is rugged, mountainous terrain with peaks that reach an elevation of 7,900 feet. In the upper 25 miles, the river flows through a narrow valley and has an average fall of about 230 feet per mile. In the lower 5-mile reach, the Dosewallips River winds through low lands that are subject to inundation during high flows. The gradient in this reach averages 3 feet per mile, and the low water channel varies from 100 to 150 feet in width.

### Flood Plain

The flood plain of the Dosewallips River extends approximately 5 miles upstream from the mouth and comprises 250 acres of land. On the right bank, 62 acres are in the flood plain, including 47 acres within the Dosewallips State Park upstream and downstream from U.S. Highway 101. A 30-acre campground has 156 tent and trailer spaces, roadways, parking areas, electricity, water and sanitary facilities. Photo 11-3 shows part of the park.

**PHOTO 11-3. Typical camp sites, Dosewallips State Park, near the right bank of the river. Corps of Engineers 9 February 1967.**

On the left bank, 188 acres are in the flood plain. About 40 acres upstream from U.S. Highway 101 have been subdivided into small tracts. This area contains several residences, truck gardens and a school. Development has doubled in the last 10 years and this trend is expected to continue.

### History of Flooding

**Floods.** High flows on the Dosewallips River have been recorded since 1931. A discharge of 4,200 cfs measured at the gage near Brinnon is considered to be zero damage flow. Since 1931, peak discharges have exceeded zero damage flow at least 23 times, as shown in Table 11-24.

**TABLE 11-24. Peak discharges greater than zero damage (4,200 cfs at the gage near Brinnon)**

| Date | Discharge cfs | Date | Discharge cfs |
|---|---|---|---|
| 23 Jan 1931 | 4,860 | 26 Nov 1949 | 13,200 |
| 26 Feb 1932 | 4,790 | 19 Nov 1954 | 5,330 |
| 2 Nov 1933 | 4,310 | 3 Nov 1955 | 8,050 |
| 21 Dec 1933 | 5,980 | 9 Dec 1956 | 5,430 |
| 5 Nov 1934 | 10,900 | 24 Feb 1958 | 5,180 |
| 25 Jan 1935 | 5,780 | 8 Jan 1959 | 4,300 |
| 1 Jan 1939 | 4,220 | 29 Jan 1960 | 6,600 |
| 8 Dec 1939 | 4,310 | 15 Jan 1961 | 7,520 |
| 15 Dec 1939 | 4,220 | 4 Feb 1963 | 7,980 |
| 2 Dec 1941 | 6,370 | 21 Oct 1963 | 5,610 |
| 7 Feb 1945 | 4,950 | 1 Dec 1966 | 6,150 |
| 18 Oct 1947 | 5,740 | | |

A flow exceeding 8,000 cfs causes major damage, and has occurred at least three times during the period of record.

Major discharges and their probable recurrence intervals are shown in Table 11-25 with the estimated discharges of 50 and 100-year floods.

**TABLE 11-25, Major floods and estimated damages**

| Date of Frequency | Peak Discharge at Brinnon Gage (cfs) | Average Recurrence (years) | Current Estimated Damages |
|---|---|---|---|
| 26 Nov 1949 | 13,200 | 83 | $137,000 |
| 5 Nov 1934 | 10,900 | 36 | 108,000 |
| 3 Nov 1955 | 8,050 | 11 | 56,000 |
| 50-year flood | 11,700 | 50 | 117,500 |
| 100-year flood | 13,600 | 100 | 142,000 |

Figure 11-8 shows the estimated probability of annual maximum flows for the Dosewallips River.

**Flood Damages.** Average annual damages are estimated to be $11,600, primarily to the Dosewallips State Park. The State Park has been inundated by floodwater at least six times in recent years: January 1959, 1960 and 1961; February 1963, November 1964 and December 1966. Flooding is aggravated by the deposition of debris, log jams, the formation of gravel bars, and the growth of trees in the channel.

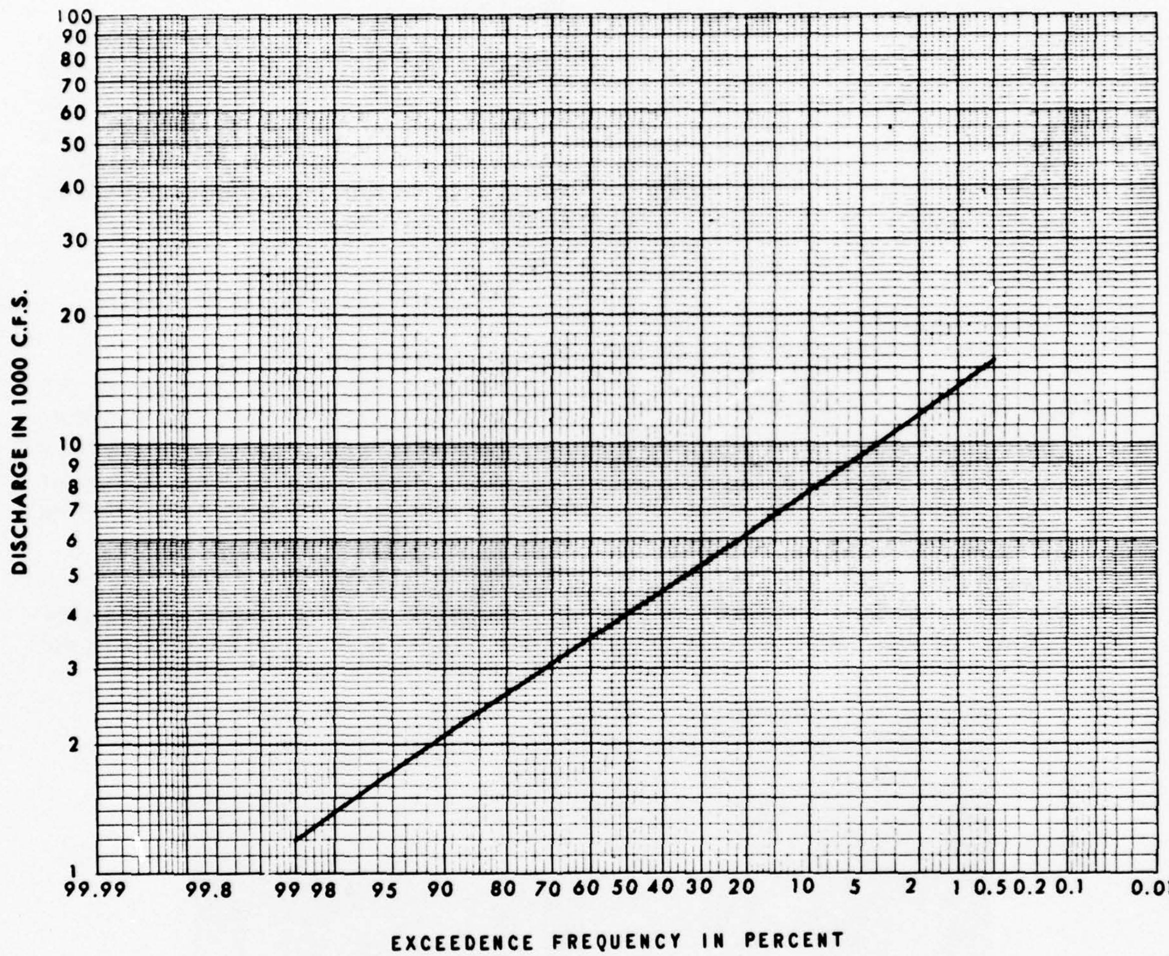



**FIGURE 11-8. Frequency curve of annual maximum peak flows, Dosewallips River near Brinnon**

Photograph 11-4 shows siltation in the park after the December 1966 flood.

Table 11-26 tabulates flood damages by the general damage categories described in the Puget Sound Area Section of this appendix and the percentage of the total damages in each category caused by major floods.

**TABLE 11-26. Flood damage distribution—Dosewallips River**

| Category | Percent of Total Damages |
|---|---|
| Recreation | 65 |
| Buildings & equipment | 27 |
| Other | 8 |
| TOTAL losses and damages | 100 |

## Existing Flood Control Measures

A low levee on the right bank of the Dosewallips River extends along the upstream limits of the Dosewallips State Park. The levee is about 500 feet long, constructed of gravel borrowed from the river, faced with about 1,000-pound rock, and deadended on the downstream end. The levee is neither strong enough nor high enough to prevent flooding, and was severely damaged by high water in December 1964. In that same month, the Washington State Parks and Recreation Commission requested Federal assistance to eliminate the flood threat to the park. In 1967 the Corps of Engineers initiated a study of this problem.

## Flood Problems

Overbank flooding begins when discharges exceed 4,200 cfs, a flow with a recurrence interval of about once in two years. Bank erosion and flooding often are intensified by the deposition of sand and gravel in the channel and debris jams, and are most serious along the right bank in the reach bordering the Doeswallips State Park.

# PRESENT AND FUTURE NEEDS

## Evaluation of Present Situation

The flood plain contains approximately 250 acres including a portion of Dosewallips State Park, several residences, truck gardens, one school, and a forty-acre development. Average annual damages are estimated to be $11,600 with the majority resulting from damage to the Dosewallips State Park.

## Flood Control Needs

**Prevention of Flood Damages.** Based on the methodology and considerations previously discussed

PHOTO 11-4. Sandy silt deposited in Dosewallips State Park by 1 December 1966 flood. Corps of Engineers, 6 December 1966.

for the Puget Sound Area, anticipated flood damages in the flood plains of the Dosewallips River Basin are expected to increase by the percentages as shown in Table 11-27.

**TABLE 11-27. Percentage increases in productivity levels and developments for specified periods**

| Category of Damage | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Recreation | 35 | 55 | 55 |
| Other | 35 | 55 | 55 |

Application of these percentages to the average annual damages based on 1966 prices and conditions provides an indication of future damages at 1966 prices if additional flood protection is not provided. Table 11–28 shows that the combination of all categories of damage are expected to increase from about $11,600 in 1966 to $40,000 by the year 2020.

**TABLE 11-28. Existing and future annual damages (in thousands of dollars)**

| | Under Development Levels of | | | |
|---|---|---|---|---|
| Category | 1966 | 1980 | 2000 | 2020 |
| Buildings & equipment | $ 3,000 | $ 4,000 | $ 6,000 | $10,000 |
| Recreation | 8,000 | 11,000 | 17,000 | 27,000 |
| Other | 600 | 1,000 | 2,000 | 3,000 |
| TOTAL | $11,600 | $16,000 | $25,000 | $40,000 |

**Optimum Flood Plain Use.** The flood plain of the Dosewallips River basin has excellent potential for additional recreational and summer home development if adequate flood protection can be provided.

## Summary of Flood Control Needs

The average annual flood damages of $11,600 need to be reduced. The majority of this damage occurs to Dosewallips State Park. The Dosewallips flood plain and Dosewallips State Park have excellent potential for further development if additional flood protection can be provided.

# MEANS TO SATISFY NEEDS

## Flood Control Objectives

The flood control objectives are to reduce existing and future flood damages and permit optimum use of the flood plain by both structural and non-structural methods consistent with economic justification. Non-structural measures would include flood plain management consistent with the flood protection provided.

## Opportunities for Structural Measures

**Upstream Storage.** Suitable upstream storage sites exist on the Dosewallips River. Costs for developing these sites as single-purpose flood control projects were not estimated because of the obviously low resulting benefit-cost ratios.

**Levees.** Levees could be constructed on both the left and right banks from the rivers mouth to approximately 5 miles upstream to protect the flood plain lands.

## Solutions to Flood Control Needs

**General.** Features of the flood control plan are detailed in Table 11-29 and shown on Figure 11-6. Levees and flood plain management are the nucleus of the flood control plan.

**Sequence of Development.**

**To 1980.** A levee system could be constructed to protect Dosewallips State Park against floods with a recurrence interval of at least 50 years and flood plain management should be implemented.

**TABLE 11-29. Flood control plan, Dosewallips River Basin**

| Flood Control Feature | Sequence of Development to 1980 | to 2000 | to 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|
| Levees | | | | |
| Protection of Dosewallips State Park | X | | | $150,000 |
| Levee on Left Bank River Mile 0 to River Mile 5 | | | X | 500,000 |
| Flood Plain Management | X | X | X | 16,000 |
| TOTAL COST OF PLAN | | | | $666,000 |

**1980 to 2020.** Levees could be constructed on the left bank to protect the remainder of the flood plain if demand for intensive use of the flood plain justifies their construction.

**Economic Analysis for 1980 Level of Protection.** The cost of levee construction for protection of Dosewallips State Park is estimated to be $150,000 based on 1966 prices. Annual costs were computed using 4-5/8 percent interest, a 50-year project life and the average annual cost of maintenance. These annual costs are estimated to be $11,000 and the annual benefits are estimated to be $11,500.

**Accomplishments.** The 62-acre right bank flood plain containing Dosewallips State Park would be provided at least 50-year protection prior to 1980. Construction of a levee system on the left bank could provide adequate protection for the remaining 190 acres of the flood plain.

**Alternatives Considered.** Upstream storage was considered as an alternative flood control measure; however, the cost of providing this storage would be much greater than constructing levees.

Flood proofing of existing buildings was evaluated as an alternative to major flood protective works for reduction of present and future flood damages. Approximately 25 percent of the estimated $11,600 average annual flood damages or about $3,000 occurs to buildings. A high percentage of these buildings are wood frame construction and flood proofing would require structural treatment that is economically infeasible. This alternative would not meet the present or future needs for optimum development of recreation facilities.

### Summary

Overbank flooding occurs on a frequency of about once every two years. Average annual flood damages based on 1966 conditions are estimated to be $11,600 and the damages that would result from a flood with an estimated recurrence interval of 100 years are estimated to be $124,000. Damages result primarily to facilities in Dosewallips State Park.

Reduction in flood damages and protection adequate for optimum development of Dosewallips State Park can be provided by levee construction.

# BIG QUILCENE RIVER BASIN

## PRESENT STATUS

### Stream System

The Big Quilcene River system rises in the Olympic National Forest and flows easterly about 18 miles to Hood Canal. Average annual precipitation in the watershed varies from 45 to 75 inches and the average annual runoff is 43 inches. Most of the watershed is remote and forested, and development is limited to the delta.

### Flood Plain

The flood plain of the Big Quilcene River comprises about 171 acres and includes a portion of the town of Quilcene. A 76-acre area on the left bank is characterized by old river channels, sloughs and swamps. Most of the area is covered with brush and second growth timber, and improvements consist of six residences, two house trailers and a floral enterprise. The 95-acre area on the right bank has an elevation about 5 feet higher than that of the left bank, and improvements include 28 well constructed and maintained residences and paved roads. A federally-owned fish hatchery is located at the mouth of Penny Creek.

A maximum of 26.2 cfs is diverted from the Big Quilcene River at a diversion works 9 miles upstream from the town of Quilcene. A pipeline 30 inches in diameter carries the water by gravity flow to a desilting reservoir, thence to Port Townsend for municipal and industrial water supply.

### History of Flooding

**Floods.** High flows on the Big Quilcene River have not been recorded. A gage near the rivermouth has recorded the flow only once, in 1926. A gage has been in operation on Penny Creek since 1949, but records runoff from only 6.78 square miles.

A discharge of 1,930 cfs is considered to be zero damage flow and to have a recurrence interval of about once in 2.4 years. A flow exceeding 3,000 cfs is expected to cause major damage. Figure 11-9 shows the estimated probability of annual maximum flows for the Big Quilcene River near Quilcene.

**Flood Damages.** Estimated average annual damages are $8,500 and those from a 100-year flood are $99,000, as shown in Table 11-30. Most of the damage is to buildings and equipment.

PHOTO 11-5. Looking upstream from the county road bridge in the town of Quilcene. Corps of Engineers photo, December 1966.

**TABLE 11-30. Major floods and estimated damages**

| Date or frequency | Peak Discharge at Quilcene (cfs) | Average Recurrence Interval (years) | Current Estimated Damages |
|---|---|---|---|
| 1 Dec 1966 | 2,760 | 5 | $ 2,040 |
| 10-year flood | 3,400* | 10 | 35,800 |
| 100-year flood | 6,000* | 100 | 99,000 |

* Estimated

Table 11-31 tabulates flood damages by the general categories described in the Puget Sound Area Section of this appendix and the percentage of total damages in each category from major floods.

**TABLE 11-31. Flood damage distribution—Big Quilcene River**

| Category | Percent of Total Damages |
|---|---|
| Developments & equipment | 86 |
| Transportation facilities | 6 |
| Other | 8 |
| TOTAL losses and damages | 100 |

### Existing Flood Control Measures

A short levee along the right bank of the river upstream from the county road bridge protects a portion of the town of Quilcene from minor floods. The levee is approximately 3 feet high and riprapped with large rock, but is in poor condition. A small berm just downstream from the levee contains minor flows that overtop or outflank the levee.

Low levees downstream from the bridge protect the southern part of the town of Quilcene from minor floods. The levees extend along both banks of the river for several hundred feet.

Low dikes on Quilcene Bay protect part of the delta from inundation by salt water during high tides.

### Flood Problems

High velocity flows exceeding 1,930 cfs overtop low levees along the Big Quilcene River about every two years, flood residential developments in the flood plain, and erode the streambanks.

## PRESENT AND FUTURE NEEDS

### Evaluation of Present Situation

Approximately 35 residences, a floral enterprise, and a county road system are within the flood

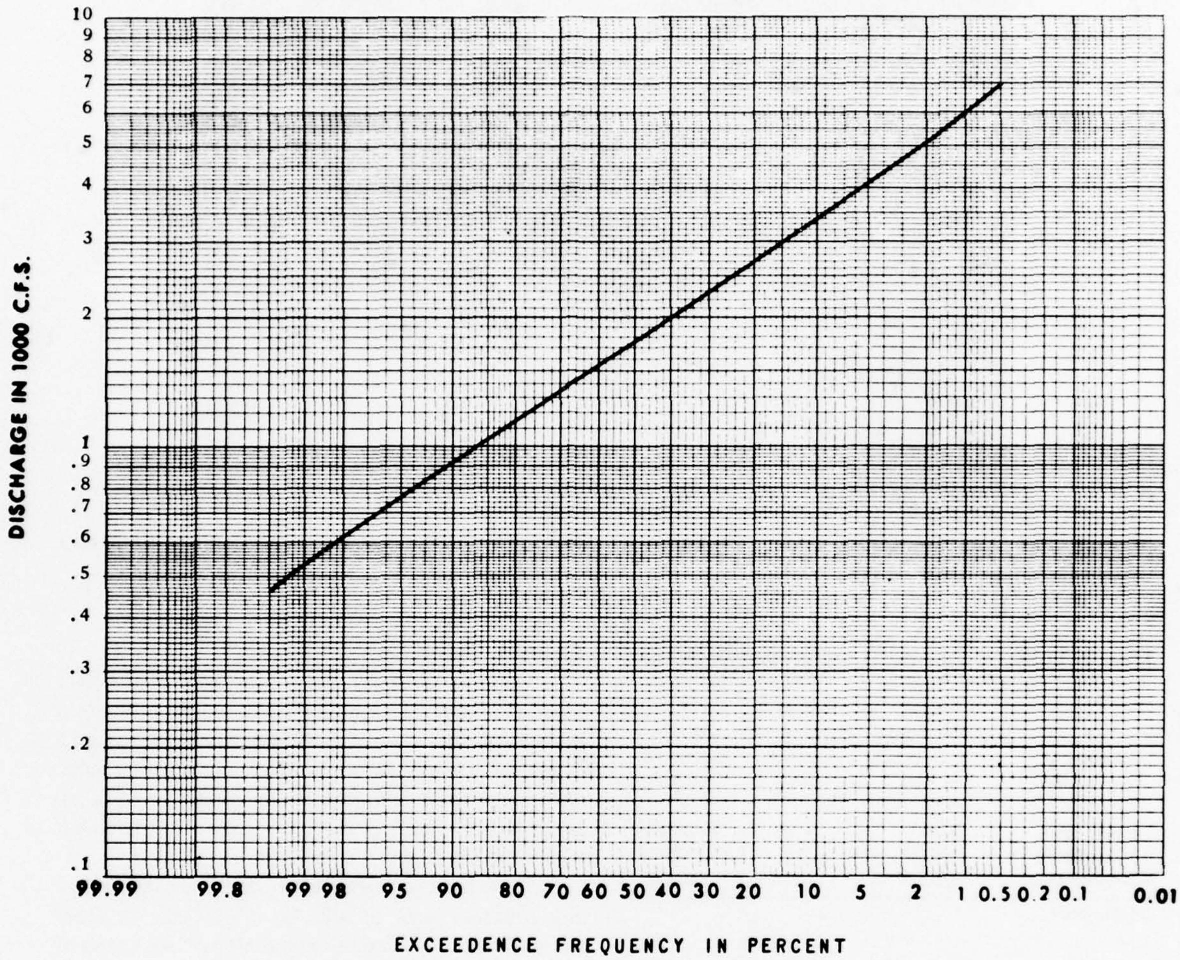



**FIGURE 11-9. Frequency curve of annual maximum peak flows, Big Quilcene River near Quilcene**

plain of the Big Quilcene River. Estimated average annual damages are $8,500. The existing flood control system protects the flood plain from minor flood discharges and provides some protection against streambank erosion. Residences and transportation facilities would be damaged by major flood discharges.

### Flood Control Needs

**Prevention of Flood Damages.** Based on the methodology and considerations previously discussed for the Puget Sound Area, anticipated flood damages in the flood plains of the Big Quilcene River are expected to increase by the percentages as shown in Table 11-32.

**TABLE 11-32. Percentage increases in productivity levels and developments for specified periods**

| Category of Damage | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Buildings & Equipment | 35 | 55 | 55 |
| Other | 35 | 55 | 55 |

Application of these percentages to the average annual damages based on 1966 prices and conditions provides an indication of future damages at 1966 prices if additional flood protection is not provided. Table 11-33 shows that the combination of all categories of damage are expected to increase from about $8,500 in 1966 to $28,000 by the year 2020.

**TABLE 11-33. Existing and future annual damages (in thousands of dollars)**

| Category | Under Development Levels of 1966 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Buildings & Equipment | $7,000 | $10,000 | $15,000 | $23,000 |
| Transportation Facilities | 500 | 1,000 | 1,000 | 2,000 |
| Other | 1,000 | 1,000 | 2,000 | 3,000 |
| TOTAL | $8,500 | $12,000 | $18,000 | $28,000 |

**Optimum Flood Plain Use.** Additional undeveloped area is available for expansion of the urban area of the town of Quilcene providing adequate flood protection can be provided.

### Summary of Flood Control Needs

The average annual damages of $8,500 need to be reduced. Nearly all of this damage occurs to residences and related facilities in and near the town of Quilcene. The undeveloped portion of the flood plain is ideally located for further urban expansion providing that additional flood protection can be provided.

## MEANS TO SATISFY NEEDS

### Flood Control Objectives

The flood control objectives are to reduce existing and future flood damages and permit optimum use of the flood plain by both structural and non-structural methods consistent with economic justification. Non-structural measures would include flood plain management consistent with the flood protection provided.

### Opportunities for Structural Measures

**Upstream Storage.** Suitable upstream storage sites exist on the Big Quilcene River. Costs for developing these sites as single purpose flood control projects were not estimated because of the obviously low resulting benefit-cost ratios.

**Levees.** A levee 6,000 feet long could be constructed to protect the 95-acre right bank flood plain.

### Solutions to Flood Control Needs

**General.** Features of the flood control plan are detailed in Table 11-34 and are shown in Figure 11-6. Flood plain management and construction of levees are the nucleus of the plan.

**TABLE 11-34. Flood control plan, Big Quilcene River Basin**

| Flood Control Feature | Sequence of Development to 1980 | to 2000 | to 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|
| Levees | | | | |
| Right bank delta | | X | | $240,000 |
| Left bank | | | X | 180,000 |
| Flood Plain Management | X | X | X | 21,000 |
| TOTAL COST OF PLAN | | | | $441,000 |

**Sequence of Development**

**To 1980.** Flood plain management should be implemented to insure that developments are consistent with the degree of flood protection provided.

**1980 to 2000.** A levee would be constructed on the right river bank to protect urban developments in the town of Quilcene.

**2000 to 2020.** Demand for intensive use of the flood plain on the left bank would require levee construction to increase the level of flood protection.

**Economic Analysis.** The cost of providing a levee on the right bank to protect the town of Quilcene is estimated to be $240,000. Annual costs were computed using 4-5/8 percent interest, a 50-year project life and the average annual costs of operation and maintenance, and are estimated to be $14,000. This compared to the estimated $8,500 annual damages indicates that this project may be economically feasible in the period 1980-2000.

**Accomplishments.** Flood plain management would prevent encroachment of development onto flood plain lands until adequate flood protection can be provided. Construction of the levee systems would protect the town of Quilcene and provide the entire 170-acre flood plain with adequate protection for intensive land use.

**Alternatives Considered.** Upstream storage was considered as an alternative flood control measure; however, the cost of providing this storage would be much greater than levee construction.

Flood plain management and flood proofing of existing buildings was evaluated as an alternative to major flood protective works for reduction of present and future flood damages. Approximately 80 percent of the estimated $8,500 average annual flood damages or about $6,800 occurs to buildings. A high percentage of these buildings are wood frame construction and flood proofing would require structural treatment that is economically infeasible. This alternative has limited application but would not provide for optimum development and utilization of the Big Quilcene flood plain.

### Summary

Overbank flooding occurs on a frequency of about once every two to three years. Average annual damages are estimated to be $8,500 and the damages that would result from a flood with an average recurrence interval of 100 years are estimated to be $99,000 based on 1966 prices and conditions. Reduction in flood damages could be accomplished by providing upstream storage but this cannot be justified on a single-purpose basis. Reduction in flood damages by levee construction may be feasible prior to 1980 or during the 1980-2000 period. Flood plain management should be initiated immediately to insure that future development in the flood plain is commensurate with the flood protection provided.

# LITTLE QUILCENE RIVER BASIN

## PRESENT STATUS

### Stream System

The Little Quilcene River is a small stream with a steep gradient. The river rises in the Olympic National Forest in rugged, mountainous terrain, flows southeasterly about 12 miles, and discharges into Quilcene Bay on Hood Canal.

### Flood Plain

The flood plain is a relatively narrow strip of land, except near the rivermouth. The flood plain contains 66 acres on the right bank and 27 acres on the left bank. Fifty-eight acres are cultivated land. A few dwellings are in the flood plain.

Port Townsend diverts a maximum of 10 cfs from this drainage for municipal and industrial water supply.

### History of Flooding

**Floods.** High flows on the Little Quilcene River have been recorded from August 1926 to October 1927 and from July 1951 to December 1957. A discharge of 500 cfs measured at the gage near Quilcene is considered zero damage flow. During the eight years of record, this flow was exceeded at least seven times with two of the years having at least two peak discharges. The flood of record was on 13 February 1954 and had a peak discharge of 820 cfs.

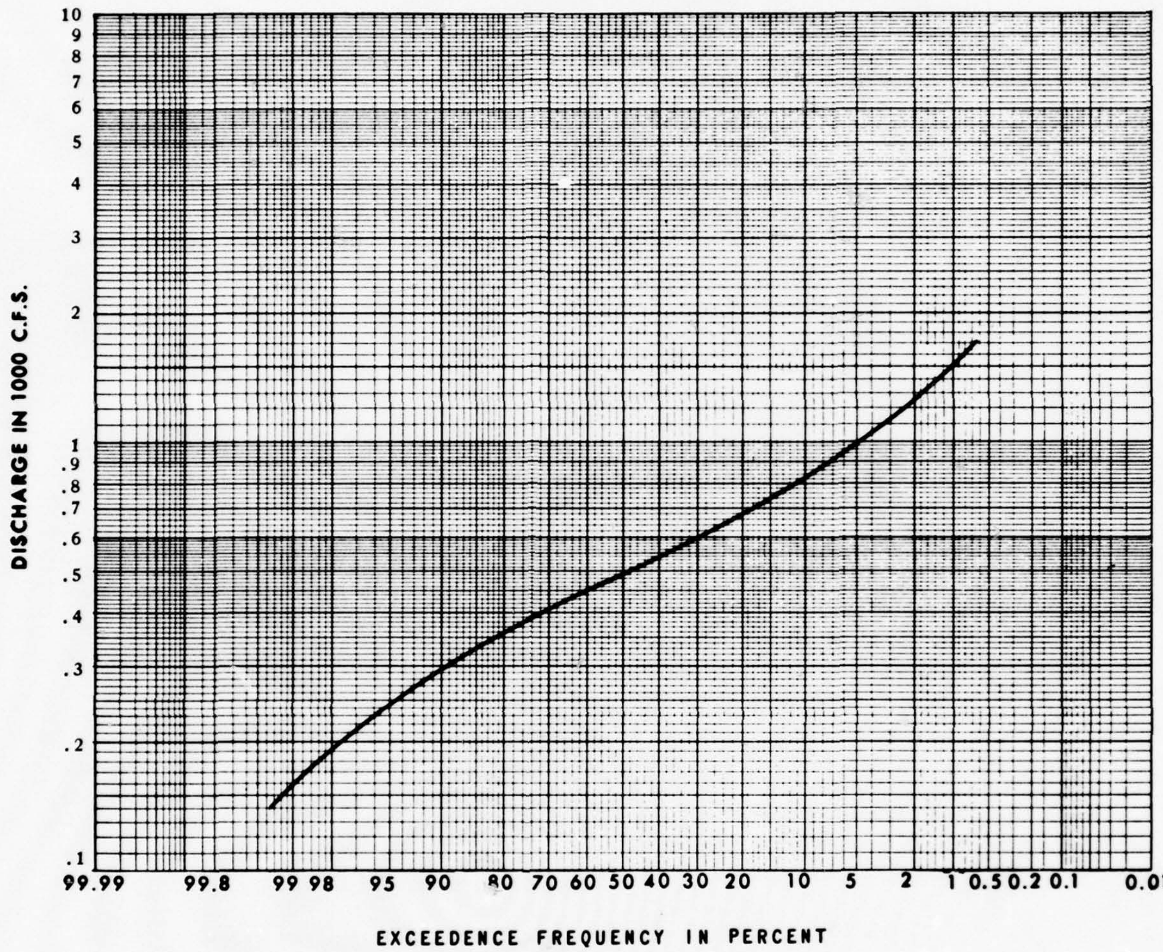



**FIGURE 11-10. Frequency curve of annual maximum peak flows, Little Quilcene River near Quilcene**

Figure 11-10 shows the estimated probability of annual maximum flows for the Little Quilcene River near Quilcene, Washington.

**Flood Damages.** Average annual damages are estimated to be $100. The damage that would result from a flood with an estimated recurrence interval of 100 years is estimated to be $1,900. Most of the damage is to buildings, equipment and agricultural land in the flood plain. Table 11-35 tabulates the flood damages by the general damage categories described in the Puget Sound Area Section of this appendix and the percentage of the total damage that would result in each category from major floods.

**TABLE 11-35. Flood damage distribution—Little Quilcene River**

| Category | Percent of Total Damages |
|---|---|
| Buildings & equipment | 77 |
| Agricultural | 10 |
| Other | 13 |
| TOTAL Losses and Damages | 100 |

## Existing Flood Control Measures

A portion of the streambank along the lower reach of the river was once protected from erosion by log cribbing. The cribbing is now rotten and ineffective.

## Flood Problem

High velocity discharges exceeding 500 cfs cause overbank flows and bank erosion about every two years. These problems are most severe in the delta.

# PRESENT AND FUTURE NEEDS

## Evaluation of Present Situation

The 90-acre flood plain of the Little Quilcene River is located along the lower one-half mile of the river. Flooding occurs frequently but because few developments are located on the flood plain, the resulting damages are minor.

## Flood Control Needs

**Prevention of Flood Damages.** Average annual flood damages are estimated to be $100 and result from damage to buildings and agricultural lands. Damages that would result from a storm with an expected recurrence interval of 100 years is estimated to be $1,900. Flood damages are minor and it is doubtful that structural facilities for prevention of flood damages can be justified. The flood plain should be zoned to insure that future developments are consistent with the protection provided.

**Optimum Flood Plain Use.** Flood protection in excess of 100 years would allow urban and suburban use of the flood plain area for future expansion of the town of Quilcene.

## Summary of Flood Control Needs

Flood damages on the Little Quilcene flood plain are low because development is limited. The flood plain should be zoned to insure that future developments are consistent with the protection provided.

# MEANS TO SATISFY NEEDS

## Flood Control Objectives

The flood control objectives are to satisfy the needs as outlined in the previous section by utilizing both structural and nonstructural measures. Nonstructural measures would include flood plain management consistent with the flood protection provided.

## Opportunities for Structural Measures

**Upstream Storage.** Suitable storage sites exist on the Little Quilcene River and could be developed to provide adequate flood protection.

**Levees.** Levees could be constructed to protect the entire flood plain of the river.

## Solutions to Flood Control Needs

**General.** Features of the flood control plan are detailed in Table 11-36 and shown on Figure 11-6. Flood plain management is the nucleus of the flood control plan for the basin. However, in the event that demand for intensive use of the flood plain lands occurs, flood plain management would have to be supplemented by construction of levees to permit intensive use of the land.

**Sequence of Development**

**To 1980.** Flood plain management should be implemented to prevent encroachment of developments onto flood plain lands which are not compatible with the degree of flood protection provided.

**TABLE 11-36. Flood control plan, Little Quilcene River Basin**

| Flood Control Feature | Sequence of Development to 1980 | to 2000 | to 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|
| Levees | | | | |
| Right and left banks | | | X | $220,000 |
| Flood Plain Management | X | X | X | 6,000 |
| TOTAL COST OF PLAN | | | | $226,000 |

**1980-2020.** When the demand for intensive use of the flood plain is such that more protection should be provided, levees could be constructed.

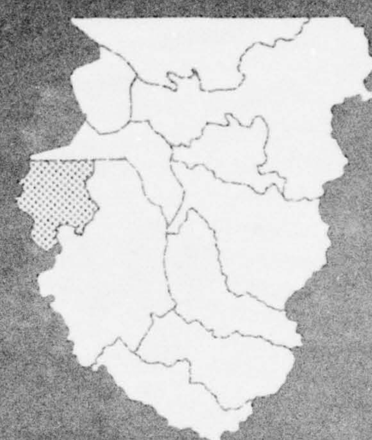
**Economic Analysis.** The cost of providing a levee system is estimated to be $220,000 based on 1966 prices. Annual costs were computed using 4-5/8 percent interest, a 50-year project life and average annual cost of maintenance. These annual costs are estimated to be $19,000 and greatly exceed the estimated annual flood damages of $100. Construction of this levee system will not be economically feasible in the foreseeable future.

**Accomplishments.** Flood plain zoning would prevent encroachment of developments onto flood plain lands until adequate flood protection is provided. Construction of the levee system would provide the entire 90-acre flood plain with adequate protection for intensive land use.

## Summary

Overbank flooding occurs on the undeveloped 93-acre flood plain of the Little Quilcene River on a frequency of about once every two years. Average annual damages are estimated to be $100 and the damage that would result from a flood with an estimated recurrence interval of 100 years is estimated to be $1,900. No structural flood protective measures can be justified in the foreseeable future. Flood plain management should be initiated immediately to insure that future flood damages remain minor.

# Elwha-Dungeness Basins



# ELWHA — DUNGENESS BASINS

## DESCRIPTION OF BASINS

### GENERAL

The Elwha and Dungeness Basins, Figure 12-1, comprise about 700 square miles of land and inland water, primarily in Clallam County, on the northern part of the Olympic Peninsula. The rugged Olympic Mountains rise to 7,000 feet above sea level and are mostly within the Olympic National Park. Many streams originate in glaciers on the higher peaks, drain northward through agricultural and forested lowlands, and discharge into the Strait of Juan de Fuca. Stream gradients are steep, as shown on the profiles, Figure 12-2. Areas under 1,000 feet in elevation are composed of recessional glacial outwash from the consolidated rocks that form the Olympic Mountains.

Maritime air masses from the Pacific Ocean and the high Olympic Range produce an unusually varied climate and precipitation pattern in these basins. Average annual precipitation exceeds 220 inches a year in the upper reaches of the Elwha and Dungeness watersheds, and decreases to an unusually low rate of approximately 16 inches along the coastal region where the rain shadow of the Olympic Mountains has its maximum effect. Approximately 75 percent of the precipitation falls during the period October through March. Average maximum monthly temperatures at Port Angeles range from 45° F. in January to 72°F in August.

### ECONOMY—PAST AND PRESENT

The Elwha and Dungeness Basins contain the only agricultural land of significance on the northern Olympic Peninsula. About 40,000 acres in these basins are suitable for agriculture; however, irrigation is required because of low precipitation.

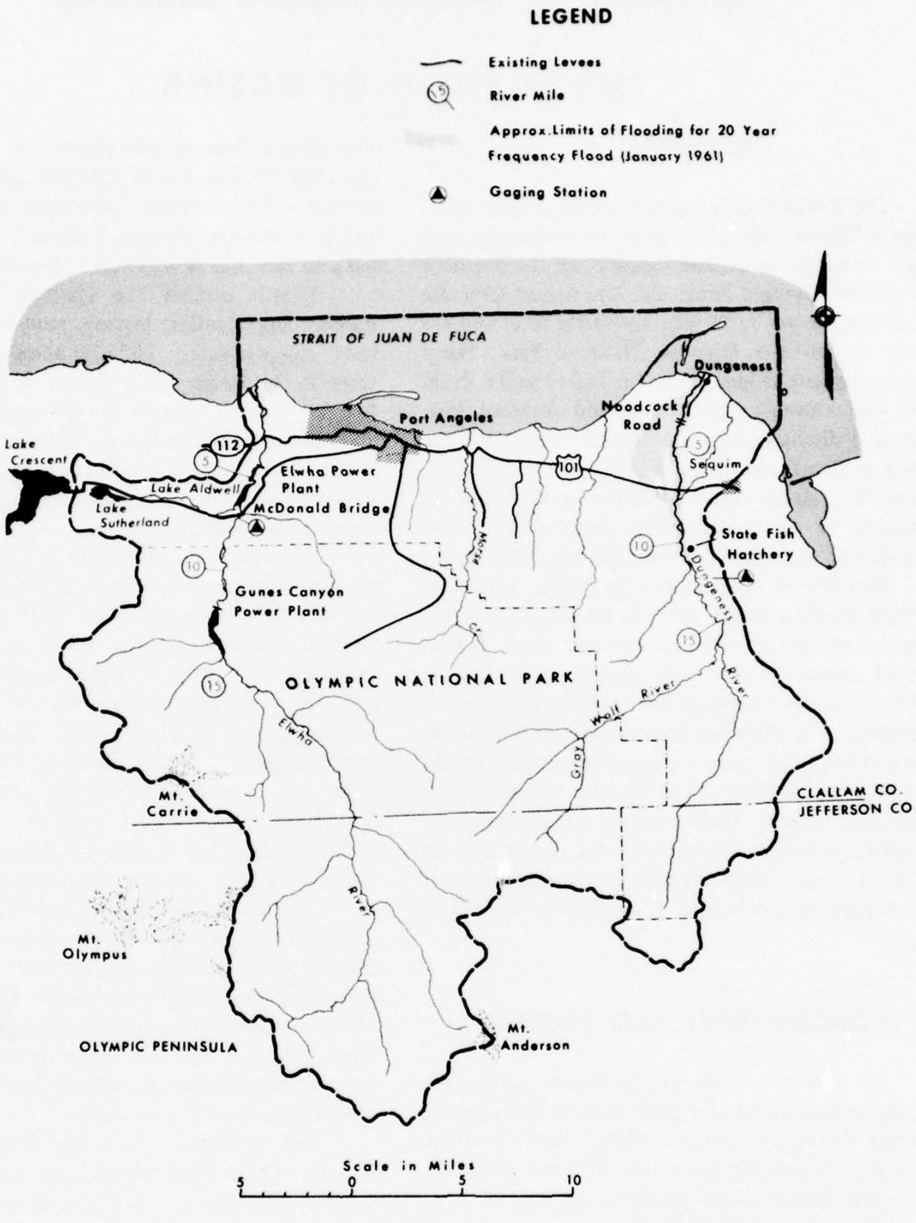
The Crown Zellerbach Corporation owns and operates two hydroelectric powerplants on the Elwha River. The Elwha powerplant, at approximately river mile 4, has an installed capacity of 12,000 kilowatts. The reservoir, Lake Aldwell, provides 3,000 acre-feet of usable storage, is about 4 miles long, and has a surface area of 320 acres at maximum pool elevation. The Glines Canyon powerplant, at approximately river mile 13, also has an installed capacity of 12,000 kilowatts. The reservoir, Lake Mills, provides 26,000 acre-feet of active storage, is about 3 miles long, and has a surface area of 435 acres when full.

Forests outside the Olympic National Park support large lumber, logging, pulp and paper industries. Approximately 352,000 acres of the 442,000 acres in the basins are classified as forest land, but 220,000 acres are within the Olympic National Park. The Elwha and Dungeness Rivers are important spawning and rearing streams for anadromous fish. A State-operated fish hatchery further enhances the sport and commercial fishery.

U.S. Highway 101 passes through the basins in an east-west direction. State Highway 112 parallels the coastline westerly from Port Angeles to the western boundary of the Elwha Basin. Secondary roads provide access to the Olympic National Park and the Olympic National Forest. The Chicago, Milwaukee, St. Paul and Pacific Railroad connects Port Angeles with Port Townsend. From Port Townsend, barges transport railroad cars across Puget Sound to Seattle. Port Angeles is served by a commercial airline, and port facilities accommodate oceangoing ships, sport and commercial fishing boats.

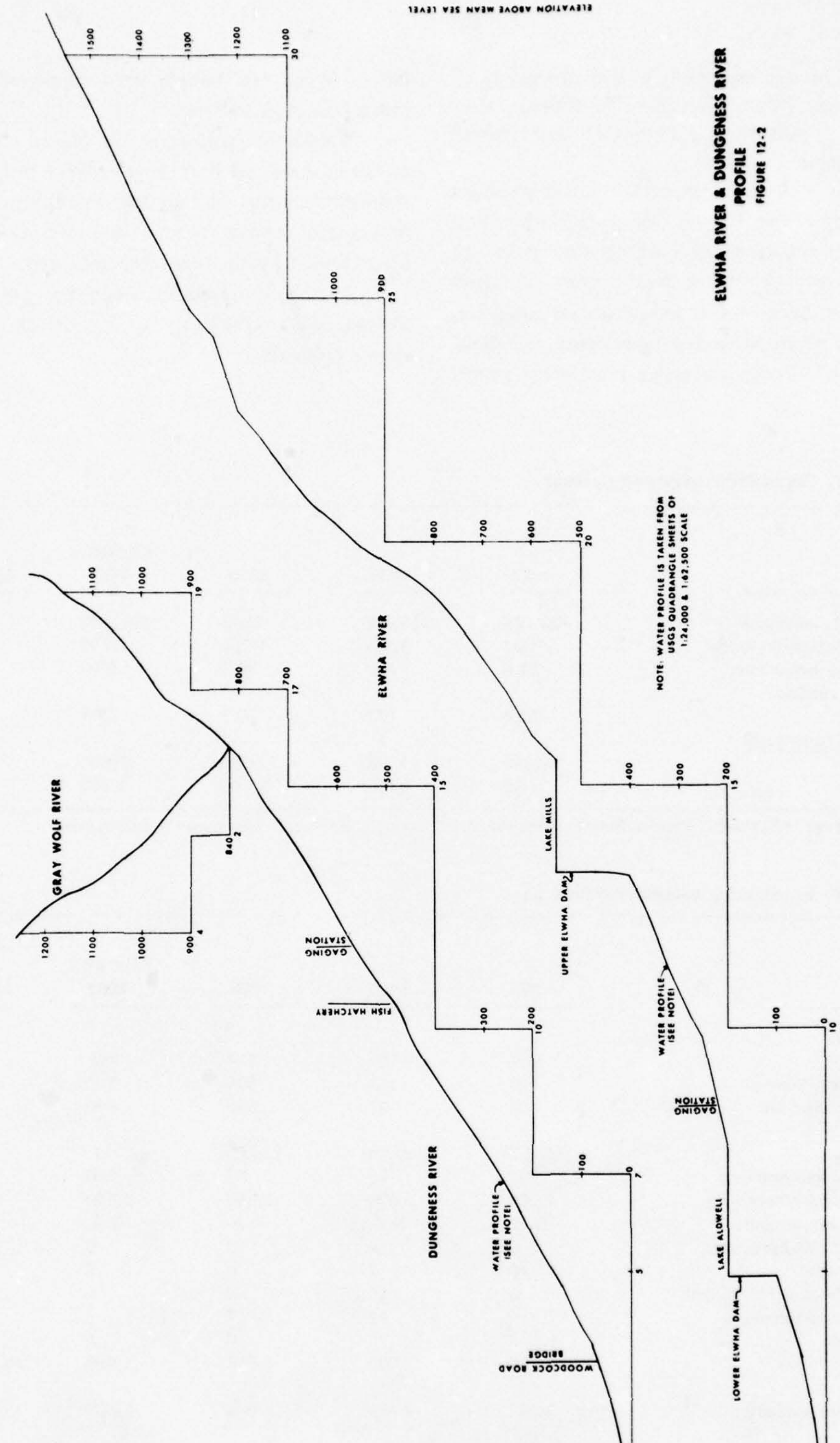
The dry climate, natural scenic beauty, numerous resorts and exceptional recreational opportunities attract tourists during the summer. The basins are becoming increasingly attractive for the establishment of retirement homes. Recreational opportunities include beachcombing and clamming on ocean beaches; sport fishing in lakes, streams and the ocean; boating, camping, hiking and picnicking.

The principal towns are Port Angeles and Sequim. Their 1966 populations were 15,000 and 1,365, respectively. The population of Clallam County, which is about half urban and half rural, increased from 21,848 in 1940 to an estimated 33,000 in 1967. The increase in population from 30,000 in 1960 to 33,000 in 1967 represents an annual growth rate of about 1.3 percent, compared to 1.6 percent for the period 1940 to 1960. The decreased rate of growth resulted from a decline in




ELWHA–DUNGENESS BASINS

**FIGURE 12-1. Flood plain and existing protective works**




ELWHA RIVER & DUNGENESS RIVER PROFILE

FIGURE 12-2

employment in the manufacture and processing of forest products. Tables 12-1 and 12-2 contain information on population, employment and growth trends for Clallam County.

Port Angeles is an important forest products manufacturing center. Crown Zellerback Corporation and Rayonier Incorporated both operate pulp and paper plants and provide a large portion of manufacturing jobs. Other forest industries including logging, lumber, plywood, and shingles employed about 1,720 in 1967. Food processing is of some importance. About 100 people were employed in 1967, primarily in fish packing.

Waterborne commerce has played a major role in the economy of Port Angeles. Principal outbound shipments consist of logs and woodpulp bound for timber-poor Asiatic countries and receipts are primarily petroleum products and general cargo.

Recreation assets although not yet fully exploited, add appreciably to income in trade and service industries.

**TABLE 12-1. Population—past and present**

| Area | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| United States (thousands) | 132,164 | 151,326 | 179,323 | 200,100 | 52 |
| Puget Sound Area (thousands) | 1,007 | 1,418 | 1,768 | 2,100 | 105 |
| Clallam County (thousands) | 21.8 | 26.4 | 30.0 | 33.6 | 54 |
| Elwha-Dungeness Basin (thousands) | 16.2 | 19.5 | 22.2 | 28.5 | 76 |
| Cities and Towns in Basin | | | | | |
| Port Angeles | 9,410 | 11,230 | 12,650 | 15,800 | 68 |
| Sequim | 680 | 1,050 | 1,160 | 1,450 | 113 |

Figures are from U.S. Census Report, Seattle Area Industrial Council, 1967, and Appendix IV, Economics.

**TABLE 12-2. Employment—past and present**

| Industry | 1940 | 1950 | 1960 | Estimated 1967 | Percent Change 1940-1967 |
|---|---|---|---|---|---|
| Clallam County | | | | | |
| Agriculture | 857 | 797 | 474 | 460 | -46 |
| Forest, Fishery, Mining | 146 | 141 | 146 | 150 | 3 |
| Contract Construction | 353 | 531 | 556 | 440 | 25 |
| Manufacturing | (3,123) | (3,654) | (3,789) | 11 | |
| Food and kindred products | 97 | 83 | 82 | 100 | |
| Lumber, wood and furniture | 1,764 | 2,008 | 1,948 | 1,720 | |
| Paper and allied products | N.A. | N.A. | N.A. | N.A. | |
| Chemical and allied products. | 0 | 9 | 0 | 0 | |
| Fabricated metal | 10 | 7 | 0 | 0 | |
| Machinery (Elect. & Non-Elect) | 8 | 14 | 29 | -- | |
| Transportation equipment | 4 | 14 | 17 | -- | |
| Primary metal | 1 | 5 | 0 | 0 | |
| All other | 1,239 | 1,505 | 1,713 | 1,650 | |
| Non-commodity industry | 3,041 | 4,359 | 5,096 | 5,680 | 87 |
| Total Employment | 7,520 | 9,473 | 10,061 | 10,190 | 36 |

## ECONOMIC TRENDS

The economy of the Elwha-Dungeness River Basin is influenced by the large number of tourists and an increasing number of retired people that are attracted to the area because of its dry climate, natural scenic beauty, numerous resorts and exceptional recreational opportunities. Other primary industries include the harvesting and manufacture of forest products and agriculture. The pattern of economic growth for the basin in the past has been slower than that of the entire Puget Sound Area and this trend is expected to continue in the future. Projections of economic growth for the West Division have been made for the years 1980, 2000, and 2020 in Appendix IV. Table 12-3 contains a forecast of population, employment, and gross regional product for the West Division and projects population for the Elwha-Dungeness River Basin. Table 12-4 converts these forecasts into rates of growth and compares these rates to those projected for the United States.

The West Division of the Puget Sound Area is forecast to grow somewhat less rapidly than the other divisions. In the 57-year period following 1963 the projected average annual growth is 1.2 percent for population, 1.3 percent for employment, and 2.7 percent for gross regional product. The major growth strength in the Elwha-Dungeness Basin is drawn from agricultural enterprises, recreation and tourism, and an increasing retirement population.

**TABLE 12-3. Economic projections**

| | 1963 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| West Division | | | | |
| Population (thousands) | 116.0 | 122.5 | 169.5 | 232.4 |
| Employment (thousands) | 37.7 | 41.9 | 57.6 | 79.5 |
| Gross Regional Product (millions of 1963 $) | 290.0 | 498.0 | 1,066.0 | 1,329.0 |
| Elwha-Dungeness River Basin | | | | |
| Population (thousands) | 28.3 | 29.8 | 41.0 | 56.6 |

**TABLE 12-4. Average annual growth trends (percent)**

| | 1963 to 1980 | 1980 to 2000 | 2000 to 2020 | 1963 to 2020 |
|---|---|---|---|---|
| United States | | | | |
| Population | 1.3 | 1.3 | 1.3 | 1.3 |
| Employment | 1.6 | 1.4 | 1.3 | 1.5 |
| Gross National Product | 4.3 | 3.9 | 4.0 | 4.0 |
| West Division | | | | |
| Population | 0.3 | 1.7 | 1.6 | 1.2 |
| Employment | 0.6 | 1.6 | 1.6 | 1.3 |
| Gross Regional Product | 3.2 | 3.9 | 1.1 | 2.7 |
| Elwha-Dungeness River Basin | | | | |
| Population | 0.1 | 1.5 | 1.6 | 1.1 |

## LAND USE TRENDS

The trend in land use is towards an increase in retirement homes, summer homes, and recreational usage and a gradually diminishing agricultural acreage. These additional developments are expected to occur in and around the town of Sequim, Dungeness, and Carlsborg, and along the saltwater at the Strait of Juan de Fuca. Much of this urban and suburban development will be located outside of the Dungeness River flood plain but developments can be anticipated in the flood plain at the town of Dungeness, on the left river bank near the river's mouth, and in and around the community of Carlsborg. No appreciable industrial use is anticipated.

# DUNGENESS RIVER BASIN

## PRESENT STATUS

### Stream System

The Dungeness River drainage contains 198 square miles, is about 35 miles long in a north-south direction and has a maximum width of about 15 miles. Most of the drainage is rugged, mountainous terrain within the Olympic National Park and the Olympic National Forest. The Dungeness River rises high in the Olympic mountains and flows northerly about 32 miles to the Strait of Juan de Fuca. Gray Wolf River, the principal tributary, joins the Dunge-

**PHOTO 12-1. Agricultural land within the Dungeness flood plain.**

ness within the Olympic National Forest. The river has a steep profile and is confined by steep canyon walls in the upper 21 miles. In the lower 11 miles, the river flows through low foothills and flat agricultural lands.

### Flood Plain

The flood plain of the Dungeness River contains approximately 2,900 acres. Developments in this area include highly productive agricultural lands, homes and farm buildings; a State fish hatchery, the water supply intake structure for the town of Sequim; the community of Carlsborg, and a summer home subdivision. The river is spanned by U.S. Highway 101, the Chicago, Milwaukee, St. Paul and Pacific Railroad, and five county bridges. Dairying and the raising of beef cattle are the principal agricultural pursuits, and most of the land is in seeded pasture and hay to support these activities. Along the lower reaches of the stream, the land is irrigated by means of diversion works and ditches.

### History of Flooding

**Flood Characteristics.** Prevailing winds during the winter months bring moisture laden air into the basins from the Pacific Ocean. However, the Olympic Mountains are a natural barrier to storms that move over the basins. Most of the precipitation occurs in the higher elevations in the form of snow, which remains on the slopes until spring or early summer. In the intermediate and lower elevations, precipitation normally falls as rain or rapidly melting snow.

Minimum flows on the Dungeness River occur during the summer months. Streamflow begins to increase in October, reaches a maximum base flow in December, and gradually decreases from January through the middle of March. As a result of rising temperatures and snowmelt, runoff begins to increase in the latter part of March and reaches a maximum in early June. Figure 12-3 shows the monthly runoff pattern and Figure 12-4 is a daily discharge hydrograph.

Discharges are measured at a gage near Sequim, about 12 miles above the rivermouth. During May and June the flow averages about 700 cfs decreases to an average of about 200 cfs in September and October, and begins to increase in November. Floodflows during the winter may be 40 times greater than the average base flow. The average annual discharge for the period 1931 to 1960 was 277,000 acre-feet.

**Floods.** High flows have been recorded on the Dungeness River from 1923 to 1930 and from 1937 to the present. During recent years a discharge of 4,000 cfs measured at the gage near Sequim has been determined to be zero damage flow. During the period of record, zero damage flow has been exceeded at least 12 times, as shown in Table 12-5.

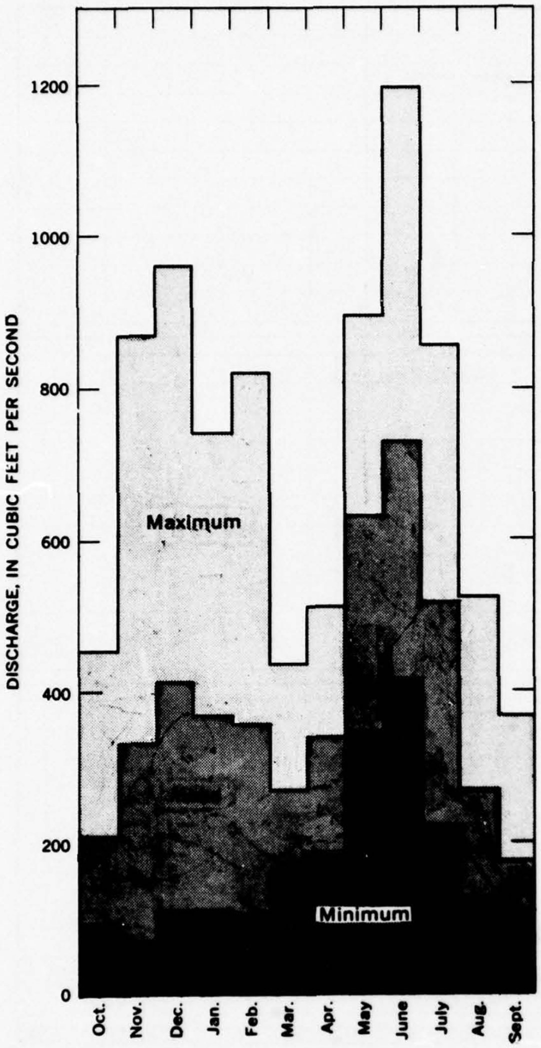



FIGURE 12-3. Maximum, mean, and minimum monthly discharges, Dungeness River near Sequim, 1931-60.

A flow exceeding 6,000 cfs causes major damage and has occurred at least five times. The highest recorded peak discharges since 1923 are shown in Table 12-6, together with estimated 50 and 100-year flood flows, probable recurrence intervals and estimated damages.

The estimated probability of annual maximum flows for the Dungeness River at Sequim is shown in Figure 12-5.

**Flood Damages.** A detailed examination was made of the flood plain in 1966 and an appraisal made to estimate the damage that would be caused by discharges of various magnitudes. Table 12-6 tabulates peak discharges and estimated damages at 1966 prices and conditions. Average annual flood damages are estimated to be $24,000.

The greater part of flood damages in the agricultural setting of the Dungeness Basin is to land, crops, farm buildings and dwellings. Damage to roads, streets, highways and bridges is significant. Table 12-7 tabulates flood damages by the general damage

**TABLE 12-5. Peak discharges greater than zero damage (4,000 cfs at gage near Sequim)**

| Discharge (cfs) | |
|---|---|
| 6,820 | 27 Nov 1949 |
| 6,750 | 3 Nov 1955 |
| 6,340 | 11 Feb 1924 |
| 5,900 | 15 Jan 1961 |
| 5,530 | 31 Jan 1924 |
| 5,380 | 28 Dec 1937 |
| 5,280 | 4 Feb 1963 |
| 4,800 | 29 Jan 1960 |
| 4,600 | 9 Feb 1951 |
| 4,270 | 9 Dec 1956 |
| 4,120 | 2 Dec 1941 |
| 4,010 | 15 Dec 1939 |

**TABLE 12-6. Major floods and estimated damages**

| Date of Frequency | Peak Discharge at Gage near Sequim (cfs) | Average Recurrence (years) | Current Interval Damages |
|---|---|---|---|
| | 14,600 (est.) | 100 | $600,000 |
| | 11,700 (est.) | 50 | 330,000 |
| 27 Nov 1949 | 6,820 | 11 | 48,000 |
| 3 Nov 1955 | 6,750 | 11 | 43,000 |
| 11 Feb 1924 | 6,340 | 10 | 32,000 |

**TABLE 12-7. Flood damage distribution**

| Category | Percent of Total Damages |
|---|---|
| Agricultural | 32 |
| Buildings & equipment | 28 |
| Transportation facilities | 31 |
| Other | 9 |
| TOTAL Losses and Damages | 100 |

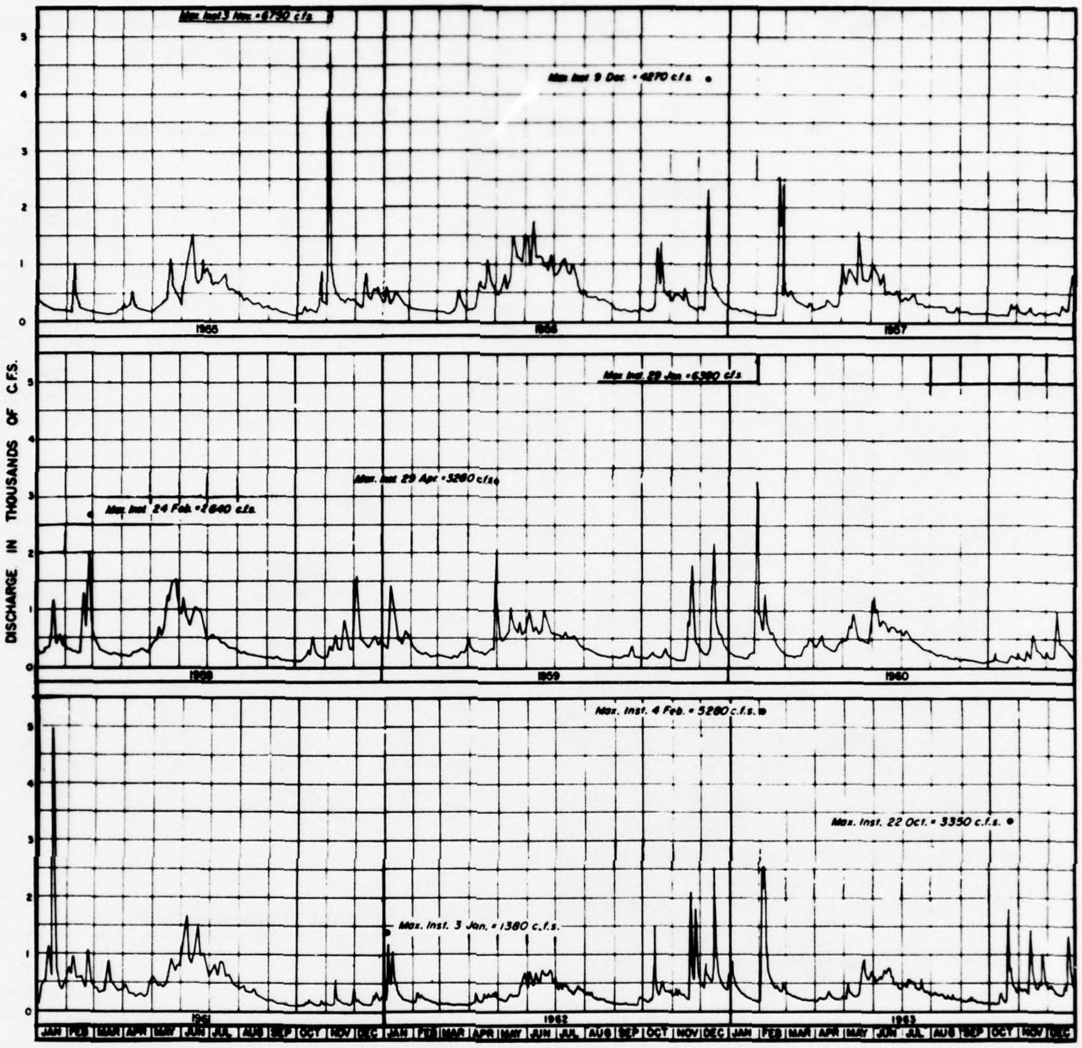


FIGURE 12-4. Daily discharge hydrograph, Dungeness River near Sequim.

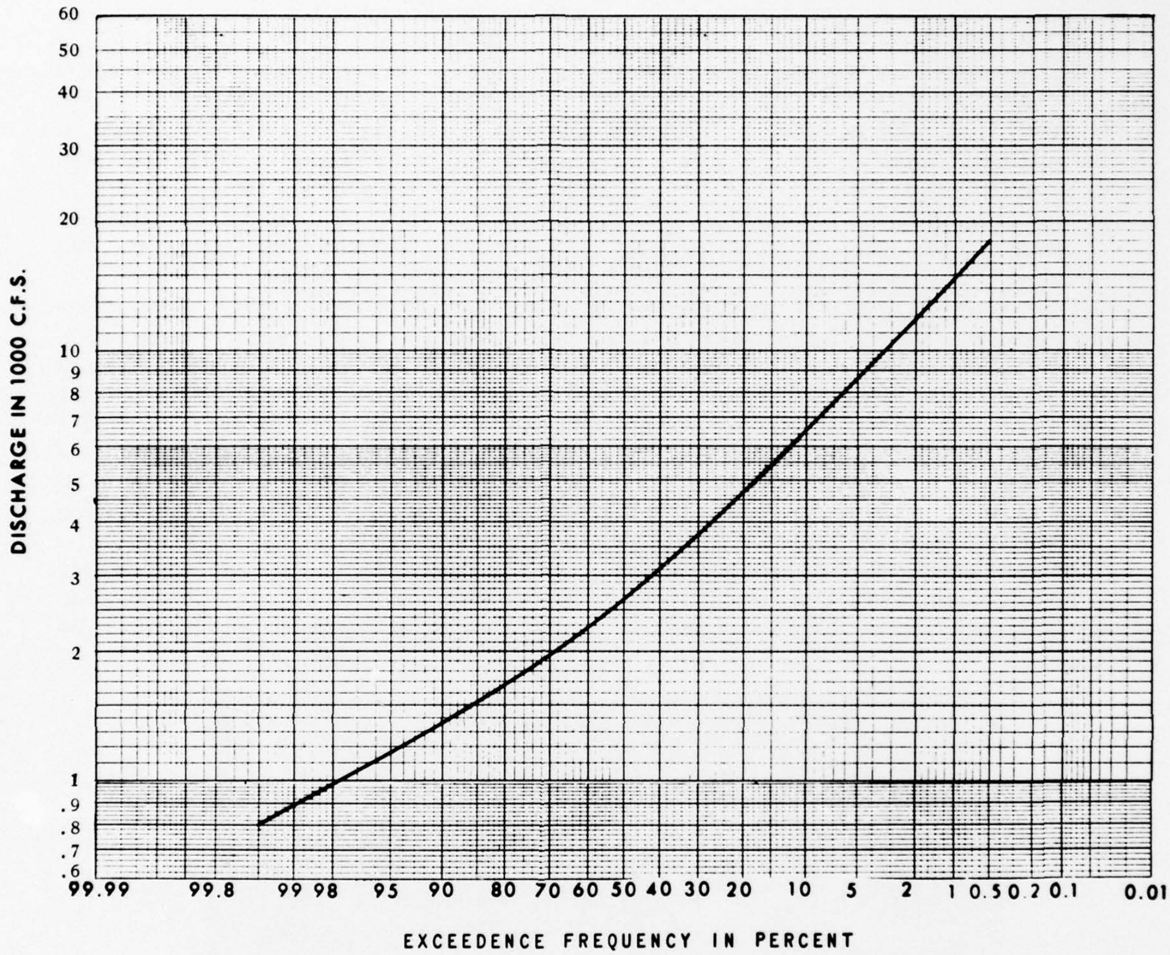



FIGURE 12-5. Frequency curve of annual maximum peak flows, Dungeness River near Sequim

categories described in the Puget Sound Area Section of this appendix, and shows the percentage of total damage that would result from major flood discharges.

## Existing Flood Control Measures

**Flood Forecasting and Warnings.** Specific flood stage forecasts are not issued for the Dungeness River at the present time. Forecasts of heavy rainfall or weather conditions that could produce floods are issued by the Weather Bureau Forecast Office, Seattle, Washington, and are given widespread dissemination over news media. Local officials can interpret these weather forecasts as warnings and act accordingly. Local flood forecasting is also extremely important because of the short interval, sometimes only a few hours, between storms and flood discharges. Clallam County has established the National Disaster System under the Sheriff's Department with assistance from the Office of Civil Defense and the County Engineer. The System is activated when flood conditions warrant.

**Flood Protective Works.**

**Levees.** A levee was constructed in 1963-64 by the Corps of Engineers along the lower 2½ miles of the right bank of the river at a cost of $440,000. The levee has a top width of 10 feet and an average height of 8 feet, and is partially riprapped on the riverward side. The levee provides protection against a flood with a recurrence interval of 200 years, an estimated flow of 18,000 cfs.

In 1964, Clallam County constructed a levee on the left bank of the river to provide some protection to the Dungeness Beach subdivision. The cost of construction was $13,700. The levee begins at approximately river mile 0.8 and extends downstream about 325 feet, has a top width of 10 feet and side slopes of 1 on 1½, and is riprapped on the riverward side. The top elevation is about 5 feet lower than that of the levee on the right bank.

**Bank Protection.** In 1950 and 1951 the Corps of Engineers completed bank protection projects on the left river bank approximately 5.5 miles above the river mouth and on the right river bank approximately 6.7 miles above the river mouth. The State of Washington contributed fifty percent of the $10,000 project cost and Clallam County provided other local cooperation, including agreement to maintain the projects after completion.

The flood of 15 January 1961 severely damaged a 500-foot reach of the Taylor Road embankment on the left bank approximately 7.5 miles above

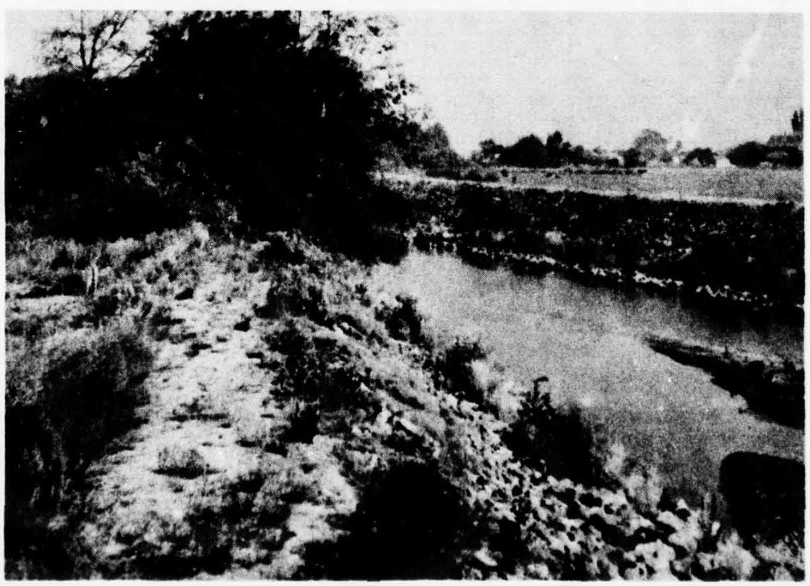


**PHOTO 12-2. The levee constructed by Clallam County extends to the trees on the left bank. The levee constructed by the Corps of Engineers is on the right bank. View is downstream from the newly constructed county bridge at river mile 0.8.**

the rivermouth. Clallam County repaired the embankment and requested the Corps of Engineers to provide a 36-inch blanket of riprap along this reach. Work was completed in October 1961 at a cost of $14,000.

**Channel Improvements.** In 1961 and 1962, Clallam County removed logs and debris along the lower 6 miles of the river to protect roads, bridges and irrigation diversion works from the threat of debris jams.

**Flood Plain Management.** The flood plain management services provided by the Corps of Engineers are discussed in the Puget Sound Area Section of this appendix. No flood plain regulations are presently in effect.

### Flood Problems

The 2,900-acre flood plain extends from river mile 11 to the rivermouth. Natural streambanks are low, ranging from 2 to 10 feet in height, and overbank flows often are increased by debris jams. Channel changes and flooding occur frequently and zero damage flow, considered to be 4,000 cfs, occurs or is exceeded about once every four years. A flow exceeding 6,000 cfs would result in major damage.

No large concentration of population occupies the flood plain. However, residences, summer homes, and agricultural lands are damaged by flooding, erosion, and the deposition of debris. Major flood discharges significantly disrupt transportation and the economy of the basin for several days.

## PRESENT AND FUTURE NEEDS

### Evaluation of Present Situation

Portions of the 2,900 acre flood plain of the Dungeness River are inundated on a frequency of about once every four years. Flood plain lands are utilized almost entirely for agriculture and contain many farm buildings and residences, as well as summer homes and transportation systems.

The existing flood control system consists of levees and streambank protective and stabilization works. The lower 2.5 miles of the right riverbank is protected by a levee that provides 200 year protection. A short levee at river mile 0.8 on the left bank provides moderate protection to the Dungeness Beach subdivision. Small emergency protective works have been constructed along riverbanks and highway embankments.

There are no storage reservoirs to regulate flows, and discharges at Sequim fluctuate widely from a maximum of about 8,000 cfs to a minimum of less than 200 cfs in late summer. Because of the steep gradient, streamflow velocities are high and the riverbanks are often eroded during high water periods. The river carries a heavy bedload which is deposited in the lower reaches. When debris accumulates at bedload deposits, the riverflow is directed into exposed riverbanks, causing further erosion and the loss of land. These conditions constrain use of the flood plain to a level of agriculture and development which can withstand periodic flooding.

Flooding problems in small watersheds tributary to the Dungeness River are minor, however, over-irrigation of agricultural lands contributes to flooding in some areas.

### Flood Control Needs

**Prevention of Flood Damages.** Average annual damages are estimated to be $24,000 and result from damages to crops and farmlands, residences, utilities and transportation systems. Damages that would result from a storm with an expected recurrence interval of 100 years are estimated to be $600,000. Flood damages must be reduced and flood plains zoned to insure that future development of these lands is orderly and consistent with the protection provided.

Based on the methodology and considerations previously discussed for the Puget Sound Area, anticipated flood damages in the flood plains of the Dungeness River Basin are expected to increase by the percentages as shown in Table 12-8.

**TABLE 12-8. Percentage increase in productivity levels and developments for specified periods**

| Category of Damage | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Agriculture | 18 | 26 | 26 |
| Non-Agriculture | 45 | 50 | 55 |

Application of these percentages to the average annual damages based on 1966 prices and conditions provides an indication of future damages at 1966 prices if additional flood protection is not provided. Table 12-9 shows that the combination of all categories of damage are expected to increase from about $24,000 in 1966 to $67,000 by the year 2020.

**TABLE 12-9. Existing and future annual damages (in thousands of dollars)**

| Category | Under Development Levels of 1966 | 1980 | 2000 | 2020 |
|---|---|---|---|---|
| Agriculture | $ 8,000 | $ 9,000 | $11,000 | $14,000 |
| Buildings & Equipment | 7,000 | 10,000 | 15,000 | 23,000 |
| Transportation Facilities | 7,000 | 10,000 | 15,000 | 23,000 |
| Other | 2,000 | 3,000 | 4,000 | 7,000 |
| TOTAL | $24,000 | $32,000 | $45,000 | $67,000 |

**Optimum Flood Plain Use.**

**Recreation.** The flood plain of the Dungeness River has potential for recreational development. This is exemplified by the Dungeness Beach 236 lot vacation home subdivision located on the left river bank flood plain at the river's mouth. Summer homes have been constructed and additional development is anticipated within this and other portions of the flood plain.

**Agriculture.** Increased demand for agricultural products will result in a need for more intensive use of the remaining agricultural lands. Flood protection of at least twenty-five years will be required for intensive agricultural production.

### Summary of Flood Control Needs

There is a need to reduce the present average annual flood damage of $24,000 that occurs to croplands, buildings, and transportation systems in the flood plain. The trend of development is expected to result in the future growth of flood damages approximating 1-7/8 percent compounded annually unless additional flood protection is provided. Future growth of average annual flood damages are expected to be $32,000 in 1980, $45,000 in 2000, and $67,000 in 2020.

Summer and retirement home developments need increased flood protection. Agricultural lands need sufficient flood protection to allow for increased economic returns from the land. Structural flood control measures must be provided to the maximum extent that economics will permit and land areas should be managed to keep developments commensurate with the flood protection provided.

## MEANS TO SATISFY NEEDS

### Flood Control Objectives

The flood control objectives are to reduce existing and future flood damages and to permit optimum use of the flood plain by providing a higher level of flood protection through utilization of both structural and nonstructural measures. Objectives of structural measures are to provide a 25-year level of flood protection for agricultural enterprises. Nonstructural measures would include flood plain management consistent with the flood protection provided.

### Opportunities for Structural Measures

**Upstream Storage.** A preliminary investigation of a storage site at river mile 15 was made. An estimated 15,000 acre-feet of flood control storage would be required to control a flood with an estimated average recurrence interval of 100 years to a maximum discharge of 4,000 cfs; the zero damage flow of the Dungeness River at the gage near Sequim.

**Levees.** Protection by levees would require construction of approximately 8 miles of levee on the left riverbank. Protection of levees from erosion by riprap would be required. Maintenance costs are anticipated to be high because of the large amount of drift and bedload carried by the river during flood discharges.

### Solutions to Flood Control Needs

**General.** Features of the flood control plan are detailed in Table 12-10 and shown on Figure 12-6.

**TABLE 12-10. Flood control plan, Dungeness River Basin**

| Flood Control Feature | Sequence of Development to 1980 | to 2000 | to 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|
| Levees | | | | |
| Left Bank-River mile 0 to River mile 8 | | | X | $2,500,000 |
| Flood Plain Management | X | X | X | 27,000 |
| TOTAL COST OF PLAN | | | | $2,527,000 |

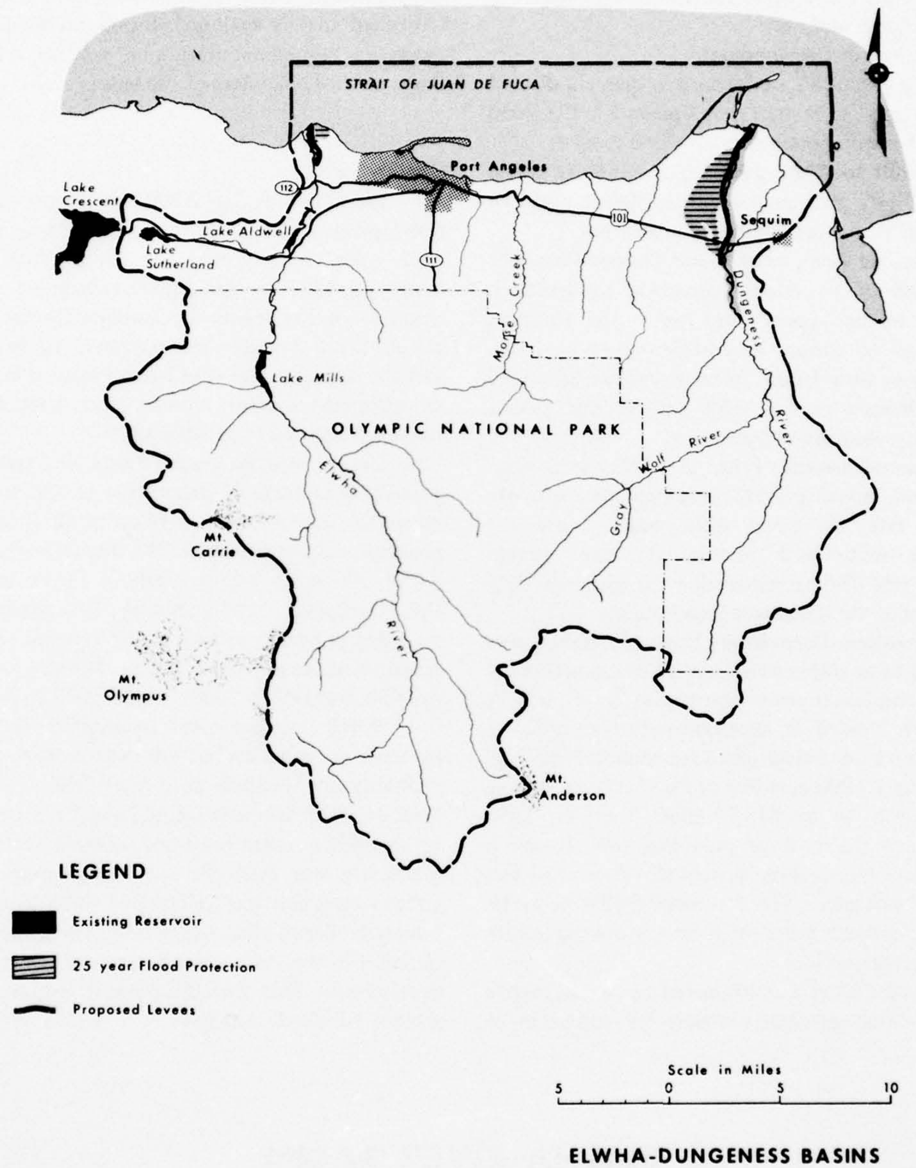



FIGURE 12-6. Proposed flood control plan and accomplishments

Flood plain management is the nucleus of this plan. However, if a demand for intensive use of the flood control plan occurs in the future, flood plain management will have to be supplemented by construction of levees to provide a degree of protection which will permit intensive land use.

**Sequence of Development.**

**To 1980.** Flood plain management should be implemented to restrict developments in the flood plain which are compatible to the flood hazards.

**1980 to 2020.** Demand for intensive land use in the flood plain may occur and levees could be constructed to provide additional protection.

**Economic Analysis of Flood Control Plan.** The annual cost of providing protection by levees is estimated to be almost four times the resulting benefits and so cannot be justified prior to 1980. Annual costs were based on an economic life of 50 years, an interest rate of 4-5/8 percent, and annual maintenance costs are included.

**Accomplishments.** Prior to 1980 flood plain management would prevent developments from encroaching into the flood plain which are not compatible with flood hazards. The levee system would provide 25-year protection for approximately 2,200 acres of the 2,900-acre flood plain.

**Alternatives Considered.** Upstream storage was considered as an alternative to levee construction for providing additional protection to the flood plain. A storage site located at approximately river mile 15 was evaluated on a single-purpose basis and the cost of providing 15,000 acre-feet of flood control storage was estimated to be $15,750,000 based on 1966 prices. Since the cost of providing this storage is much greater than a levee system this alternative was considered infeasible. Flood control should be evaluated as a project purpose in any proposed multi-purpose storage project.

Floodproofing was evaluated as an alternative to major flood protective works for reduction of present and future flood damages. Approximately 25 percent of the estimated $24,000 average annual flood damages or about $6,000 occurs to buildings. Many of these buildings are of wood frame construction and floodproofing would require structural treatment that is economically infeasible. This alternative has limited application but would not meet the flood control objectives of the basin.

## Summary

Flooding of the 2,900-acre Dungeness River flood plain occurs on an average frequency of about once every four years. The flood plain is used predominantly for agricultural enterprises, but also contains some residences and summer homes. Average annual flood damages are estimated to be $24,000 and the damages that could result from a flood with an estimated average interval of recurrence of 100 years is estimated to be $600,000.

Future average annual flood damages are expected to increase in proportion to the increase in economic activity in the flood plain if additional protection is not provided. The trend of development within the basin would result in future growth of flood damages approximating 1.6 percent compounded annually without flood control and would result in future growth of annual damages to $32,000 in 1980, $45,000 in 2000, and $67,000 in 2020.

Flood damages could be significantly reduced by levee construction but this construction cannot be economically justified until after 1980. A 100-year level of flood protection could also be accomplished by providing upstream flood control storage. This alternative was evaluated on a single-purpose flood control basis and was determined to be economically infeasible. Flood plain zoning and management are required for the entire flood plain to control future development and thereby prevent future excessive growth of flood damages.

# ELWHA RIVER BASIN

## PRESENT STATUS

### Stream System

The Elwha River drainage, containing 321 square miles, is approximately 10 miles wide in an east-west direction and 35 miles long. The topography varies from rugged, glacier-covered peaks within the Olympic National Park to forested rolling hills to sea level. The Elwha River emerges from glaciers in the Olympic Mountains, flows northerly

about 27 miles, and discharges into the Strait of Juan de Fuca. The Elwha has no major tributaries but is joined by numerous small streams.

## Flood Plain

The flood plain along the lower 2 miles of the river contains about 750 acres of land. Most of the flood plain is used for agriculture.

The river has three distinct reaches. The upper reach, above Lake Mills Reservoir in Olympic National Park, is confined by steep canyon walls and is undeveloped. The middle reach, from Lake Mills Reservoir to Lake Aldwell Reservoir, is in a narrow valley that contains two campgrounds in the Olympic National Park and an access road. The lower reach, from Lake Aldwell Reservoir to the Strait of Juan de Fuca, is within a narrow canyon for several miles, then opens into a triangular-shaped delta containing several distributary channels and some agricultural land (Photo 12-3). Agricultural lands are utilized for dairying and the raising of beef cattle.

Up to 115 cfs is diverted from the river about 1½ miles below Lake Aldwell by pulp and paper companies to supply water to their industrial plants in Port Angeles. Used water is discharged into tidewater near Port Angeles.

## History of Flooding

**Flood Characteristics.**. The streamflow characteristics of the Elwha River are similar to those of the Dungeness River. Figure 12-7 reflects these similarities in the monthly runoff pattern.

Streamflow is gaged at MacDonald Bridge at river mile 7. The flow averages 2,700 cfs during May and June, decreases to an average of 600 cfs in September, and begins to increase in October. Floodflows during the winter may be 20 times greater than the average base flow.

**Floods.** High flows have been recorded on the Elwha River from 1897 to 1901 and from 1919 to date. During recent years, a discharge of 9,000 cfs measured at the MacDonald Bridge gage was determined to be zero damage flow. During the period of record, the river has exceeded zero damage flow at least 40 times, as shown in Table 12-11. Discharges have been partially regulated by Lake Mills Reservoir since 1927.

The average annual discharge of the Elwha River for the period 1931-1960 was 1,090,000 acre-feet.

Probability curves of annual maximum flows for the Elwha River are shown in Figure 12-8.

PHOTO 12-3. Typical agricultural land in the delta and associated buildings on the right bank near the mouth of the Elwha River.

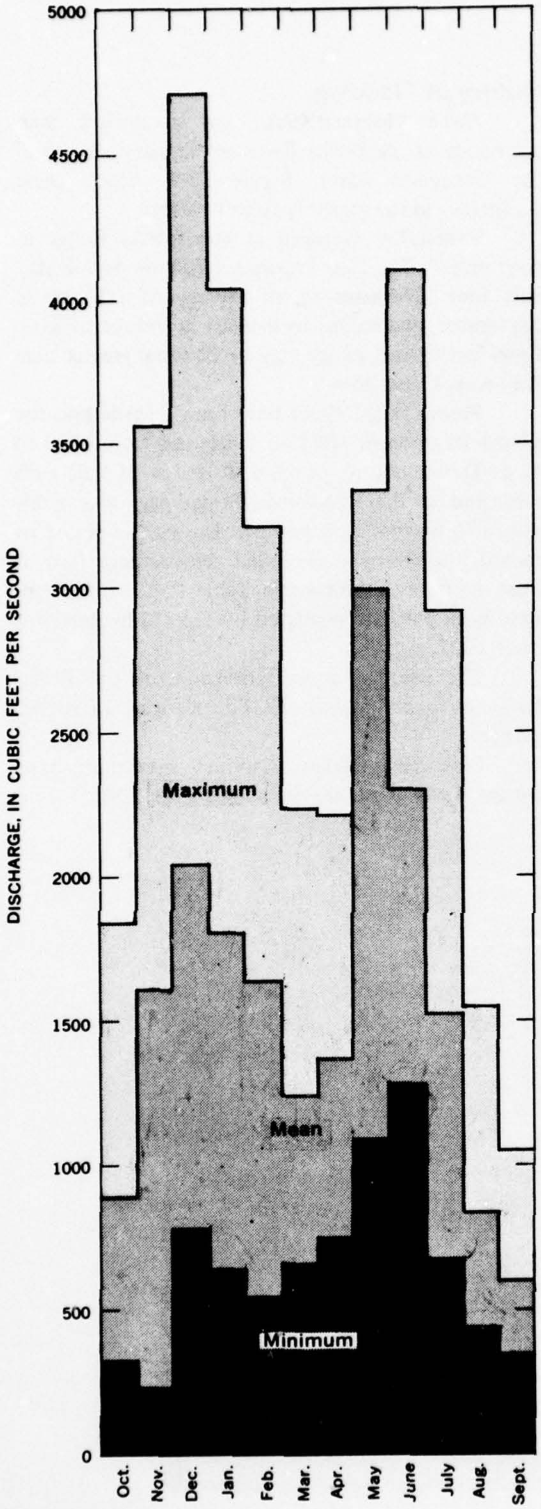



FIGURE 12-7. Maximum, mean and minimum monthly discharges, Elwha River near Port Angeles, 1931-60.

**TABLE 12-11. Peak discharges greater than zero damage (9,000 cfs at MacDonald Bridge Gage)**

| Discharge (cfs) | | Discharge (cfs) | |
|---|---|---|---|
| 41,600 | 18 Nov 1897 | 14,300 | 9 Feb 1951 |
| 33,600 | 27 Nov 1901 | 14,300 | 18 Nov 1954 |
| 30,200 | 11 Mar 1900 | 14,200 | 31 Jan 1924 |
| 30,000 | 26 Nov 1949 | 14,000 | 7 Feb 1945 |
| 26,700 | 21 Dec 1933 | 13,000 | 13, Feb 1947 |
| 25,200 | 5 Nov 1934 | 12,400 | 21 Oct 1963 |
| 22,900 | 22 Nov 1959 | 12,100 | 12 Nov 1932 |
| 22,100 | 9 Dec 1956 | 12,100 | 23 Jan 1931 |
| 22,100 | 15 Jan 1961 | 11,700 | 11 Feb 1921 |
| 21,700 | 19 Nov 1962 | 11,100 | 31 Jan 1953 |
| 21,400 | 12 Dec 1921 | 11,000 | 15 Nov 1919 |
| 21,400 | 3 Nov 1955 | 19,800 | 17 Jan 1941 |
| 20,600 | 20 Dec 1900 | 10,700 | 12 Jan 1928 |
| 18,600 | 28 Dec 1937 | 10,500 | 16 Jan 1958 |
| 18,000 | 18 Oct 1947 | 10,000 | 3 Dec 1943 |
| 17,100 | 1 Jan 1939 | 9,820 | 11 Dec 1953 |
| 17,100 | 2 Dec 1941 | 9,880 | 24 Dec 1922 |
| 16,200 | 26 Feb 1932 | 9,800 | 9 Oct 1928 |
| 15,600 | 15 Dec 1939 | 9,790 | 30 Nov 1964 |
| 15,400 | 29 Apr 1949 | 9,500 | 19 Nov 1924 |

Floods with the highest recorded peak discharges since 1897 are shown in Table 12-12, together with their probable recurrence intervals.

**TABLE 12-12. Major floods and estimated damages**

| Date of Frequency | *Peak* Discharge MacDonald Bridge Gage (cfs) | Average Recurrence Interval (years) | Current Estimated Damages |
|---|---|---|---|
| 18 Nov 1897 | 41,600 | 100 | $51,000 |
| 27 Mar 1901 | 33,600 | 40 | 29,000 |
| 11 Mar 1900 | 30,200 | 24 | 21,000 |
| 26 Nov 1949 | 30,000 | 25 | 21,000 |
| 21 Dec 1933 | 26,700 | 16 | 14,500 |

**Flood Damages.** A detailed examination was made of the flood plain in 1966 and an appraisal was made to estimate the damages that would be caused by discharges of various magnitudes. Table 12-12 tabulates the peak discharges of past floods and estimated damages at 1966 prices and conditions. Average annual flood damages are estimated to be $4,000.

Most of the damage is to agricultural lands and associated improvements in the delta. The bulk of the remaining damages is to transportation facilities, campgrounds, flood protective works, and the water

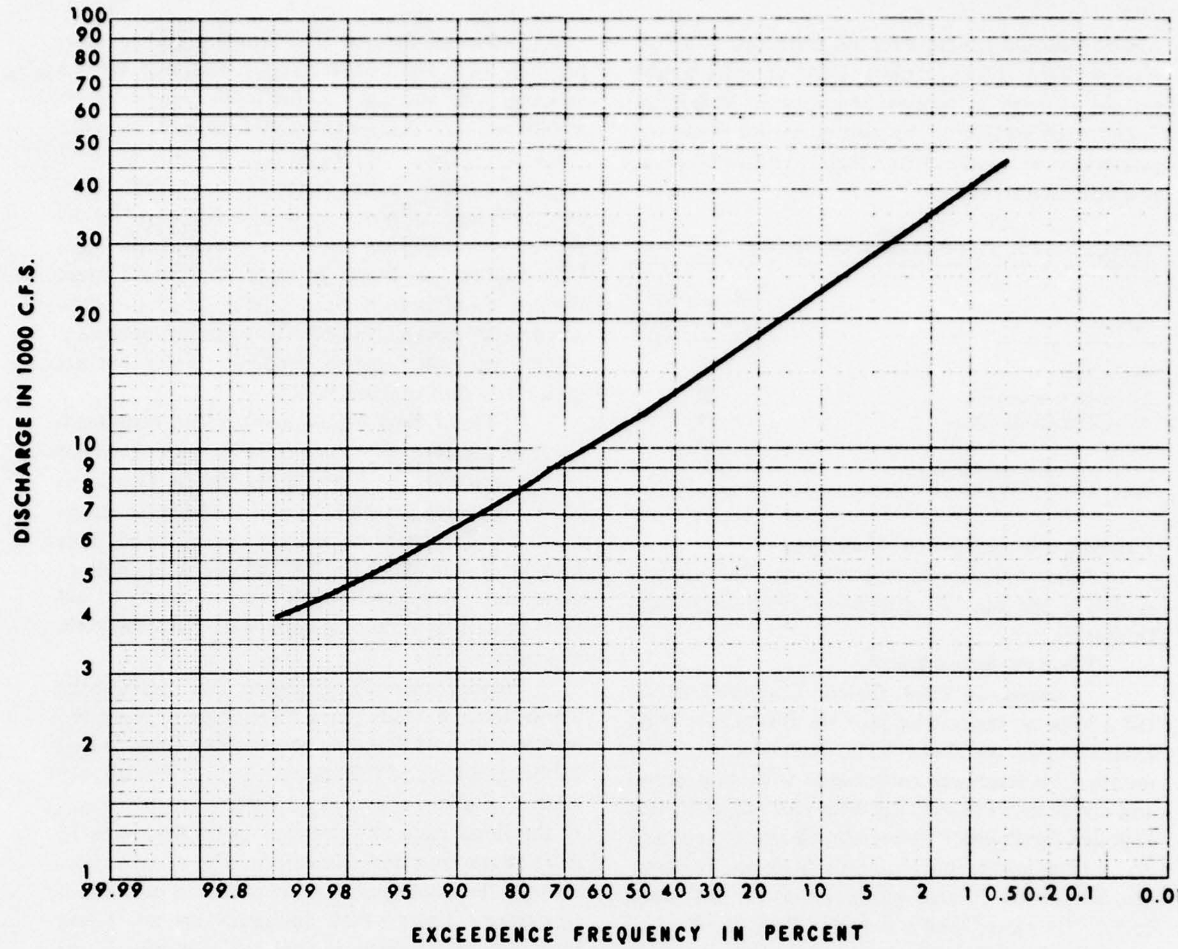



**FIGURE 12-8. Frequency curve of annual maximum peak flows, Elwha River at McDonald Bridge near Port Angeles**

supply diversion structure for industrial plants in Port Angeles. Table 12-13 tabulates flood damages by the general damage categories described in the Puget Sound Area Section of this appendix, and shows the percentage of total damage that would result from major flood discharges.

**TABLE 12-13. Flood damage distribution**

| Category | Percent of Total Damages |
|---|---|
| Agriculture | 19 |
| Buildings & equipment | 40 |
| Transportation facilities | 24 |
| Other | 17 |
| TOTAL losses and damages | 100 |

### Existing Flood Control Measures

**Flood Forecasting and Warning.** The warning system is the same as previously described for the Dungeness River.

**Flood Protective Works.**

**Levees.** In 1964, Clallam County constructed a levee on the left bank of the Elwha River that extends upstream about 1,000 feet from the rivermouth. The levee was constructed with sand, gravel and silt borrowed from the river channel, is 10 feet high and faced with 150-pound rock riprap, and has a 26-foot top width and 1 on 1½ side slopes. The levee provides about 25-year protection for a settlement called "The Place," and is shown in Photo 12-4.

The overflow spillway control channel for the Port Angeles industrial water supply system is protected by a rockfill training levee approximately 500 feet downstream from the State Highway 112 bridge. The levee is about 200 feet long and 10 feet high, and has a 12-foot top width and 1 on 1½ side slopes.

**Bank Protection.** Approximately 400 feet of the Olympic National Park access road was protected with rock riprap in 1951 by the Corps of Engineers. This project is approximately three-fourths mile upstream from the U.S. Highway 101 bridge and was completed at a cost of $17,300.

**Channel Improvements.** Several distributary channels have been formed in the delta by peak discharges. The east channel approximately 1.5 miles upstream from the rivermouth has been plugged with a gravel fill. The fill diverts moderate flood discharges into the west channel and prevents the flooding of farms on the right bank, but is overtopped by major flood discharges.

**Storage Projects.** The Crown Zellerbach Corporation owns and operates hydropower installations at Lake Mills and Lake Aldwell. The reservoirs are maintained near maximum pool elevation to produce maximum power for the company's mill in Port Angeles; however, power demands exceed the output, and the balance of power required is purchased. While no firm flood control storage is provided, the Lake Mills reservoir is drawn down about 10 to 15 feet when a flood is expected to make 4,000 to 6,000 acre-feet of storage available. This amount of storage reduces peak discharges of moderate floods, but has little effect during major floods.

**Flood Plain Management.** Flood plain management measures to reduce flood damages have not been adopted in the Elwha River Valley. The Corps of Engineers has established the Flood Plain Management Service described in the Puget Sound Area Section of this appendix. This service is available to State and local governments upon request, to aid them in developing zoning ordinances and flood plain regulations.

**Flood Problems** The 750-acre flood plain of the Elwha River extends from Lake Mills to the rivermouth. Overbank flooding occurs when flows exceed 9,000 cfs. Flows of this magnitude have a recurrence interval of about once every 1.4 years. Improvements in the flood plain are scattered along the lower 13 miles of the river and consist primarily of recreation-oriented developments. The lower delta is utilized for agriculture. Major flood discharges on the Elwha River do not seriously disrupt the economy of the basin because the principal transportation systems are not effected, very few homes are within the flood plain, and damaged facilities can be restored rapidly.

## PRESENT AND FUTURE NEEDS

### Evaluation of Present Situation

The 750-acre flood plain of the Elwha River is subject to flooding about once every 1.4 years. Flood plain lands are utilized for recreation and agriculture. Flood damages begin when flows exceed 9,000 cfs at the gage located near MacDonald Bridge. Average annual flood damages are estimated to be $4,000. Flood damage is sustained by agricultural lands, campgrounds, transportation facilties, flood protective works, and a water supply diversion structure.

The existing flood control system consists of flood control storage provided by voluntary draw-

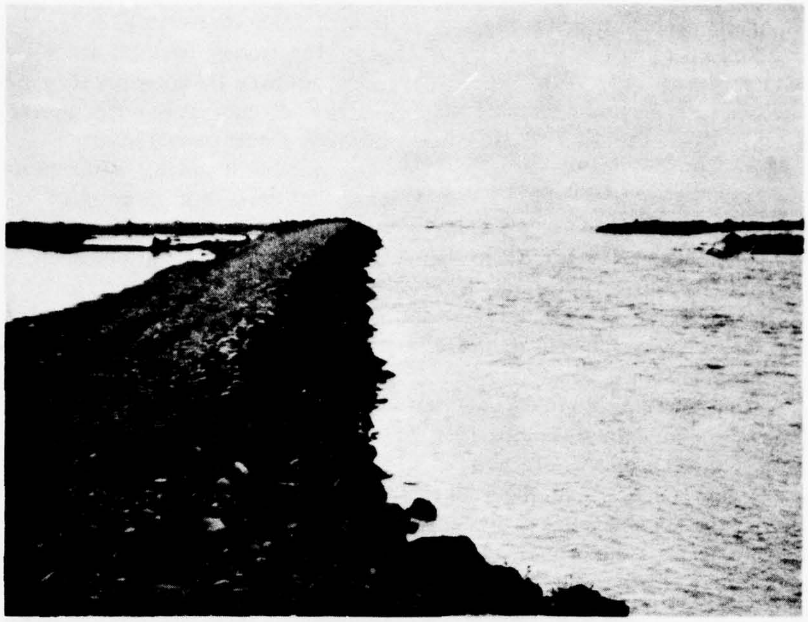


PHOTO 12-4. Levee on the left bank of the Elwha River at its mouth.

down of the Lake Mills Reservoir by the Crown Zellerbach Corporation, two levees, and a channel improvement project. The low degree of protection provided by these facilities limits use of flood plain lands to agricultural uses such as hay production or pasture. Recreational development in the upper reaches is also limited by flooding.

Small tributaries of the Elwha River have no significant flood, drainage, or erosion problems because of the lack of development and excellent vegetative cover.

## Flood Control Needs

**Prevention of Flood Damages.** Based on the methodology and considerations previously discussed for the Puget Sound Area, anticipated flood damages in the flood plains of the Elwha River Basin are expected to increase by the percentages as shown in Table 12-14.

**TABLE 12-14. Percentage increase in productivity levels and developments for specified periods**

| Category of Damage | 1966-1980 | 1980-2000 | 2000-2020 |
|---|---|---|---|
| Agriculture | 18 | 26 | 26 |
| Non-Agriculture | 25 | 40 | 85 |

Application of these percentages to the average annual damages based on 1966 prices and conditions provides an indication of future damages at 1966 prices if additional flood protection is not provided. Table 12-15 shows that the combination of all categories of damage are expected to increase from about $4,000 in 1966 to $14,000 by the year 2020.

**TABLE 12-15. Existing and future annual damages (in thousands of dollars)**

| | Under Development Levels of | | | |
|---|---|---|---|---|
| Category | 1966 | 1980 | 2000 | 2020 |
| Agriculture | $1,000 | $1,000 | $1,000 | $ 1,000 |
| Buildings & Equipment | 2,000 | 3,000 | 4,000 | 7,000 |
| Transportation Facilities | 500 | 1,000 | 2,000 | 3,000 |
| Other | 500 | 1,000 | 2,000 | 3,000 |
| TOTAL | $4,000 | $6,000 | $9,000 | $14,000 |

**Optimum Flood Plain Use.** The flood plain of the Elwha Basin has potential for additional recreational developments and for urban expansion because of its close proximity to Port Angeles. Urban expansion can be expected due to an increase in

navigation at Port Angeles and continued production of pulp and paper products as well as an increase in recreation-oriented industries.

Increased demand for agricultural products will result in a need for more intensive use of the remaining agricultural lands.

## Summary of Flood Control Needs

The Elwha River Basin is expected to be utilized predominantely as a recreational area with agriculture, forest products and hydroelectric power production continuing as important industries. The increasing demand for recreation in the Puget Sound Area will result in rapid recreational growth in this basin. Average annual flood damages under 1966 conditions are estimated to be $4,000. The trend of development is expected to result in the future growth of flood damages approximating 2 percent compounded annually unless additional flood protection is provided. Future growth of average annual flood damages are expected to be $6,000 in 1980, $9,000 in 2000, and $14,000 in 2020.

Existing flood damages are not excessive and the flood plain should be zoned to insure that future development of these lands is orderly and consistent with the protection provided.

# MEANS TO SATISFY NEEDS

## Flood Control Objectives

The flood control objectives are to reduce existing and future flood damages and permit optimum use of the flood plain through utilization of both structural and nonstructural measures. Objectives of structural measures are to provide a 25-year level of flood protection for agricultural enterprises. Nonstructural measures would include flood plain management and floodproofing consistent with the flood protection provided.

## Opportunities for Structural Measures

**Upstream Storage.** The possibility of including additional flood control storage in the existing Lake Mills and Lake Aldwell reservoirs was investigated. Lake Mills reservoir contains the only significant storage, 26,000 acre-feet, and contains only 8,000 acre-feet of storage above the spillway crest elevation that would be suitable for flood control. Approximately 50,000 acre-feet of flood control storage is required to control a 100-year flood to zero damage flow of 9,000 cfs measured at the MacDonald Bridge gage. The storage facilities are not capable of providing adequate flood control storage but the existing practice of providing some storage during flood discharge should be continued.

Additional suitable upstream storage sites may exist but were not investigated because costs of developing these sites as single-purpose flood control projects would result in extremely low benefit-cost ratios.

**Levees.** The 750-acre flood plain near the mouth of the river could be protected by levee construction. A 7,000-foot levee on the right bank would be required to provide 25-year protection.

## Solutions to Flood Control Needs

**General.** Features of the flood control plan are detailed in Table 12-16 and shown on Figure 12-6. Levees and flood plain management are the nucleus of this plan.

**TABLE 12-16. Flood control plan, Elwha River Basin**

| Flood Control Feature | Sequence of Development to 1980 | to 2000 | to 2020 | Estimated Development Costs for Projects Based on 1968 Costs |
|---|---|---|---|---|
| *Levees* | | | | |
| Right Bank, Elwha River RM 0.0 to RM 1.5 | | | X | $250,000 |
| Flood Plain Management | X | X | X | 6,000 |
| TOTAL COST OF PLAN | | | | $256,000 |

**Sequence of Development**

**To 1980.** Flood plain management should be implemented to insure that developments in the flood plain are compatible with the flood protection provided.

**1980-2020.** Levees could be constructed as they become economically feasible if more intensive use of the flood plain lands is determined to be feasible and desirable.

**Economic Analysis.** Annual costs for providing a levee on the right bank of the delta area were computed using 4-5/8 percent interest, a 50-year project life and the average annual costs of maintenance and operation are estimated to be $15,000. This

compares with $4,000 annual flood damages; therefore, construction of the levees would not be economically feasible in the near future.

**Accomplishments.** Prior to construction of levees, flood plain management could restrict developments in the flood plain to those compatible with flood hazards. When levees are constructed the entire 750-acre flood plain could be provided protection which would permit intensive land use.

**Alternatives Considered.** Upstream storage was considered as an alternate flood control feature; however, the cost of providing this storage would be much greater than a levee system and would provide the same benefits.

Flood plain management and floodproofing of existing buildings was evaluated as an alternative to major flood protective works for reduction of present and future flood damages. Approximately 40 percent of the estimated $4,000 average annual flood damages or about $1,600 occurs to buildings. These buildings are of wood frame construction and floodproofing would require structural treatment that is economically infeasible. This alternative has limited application but would not meet the flood control objectives of the basin.

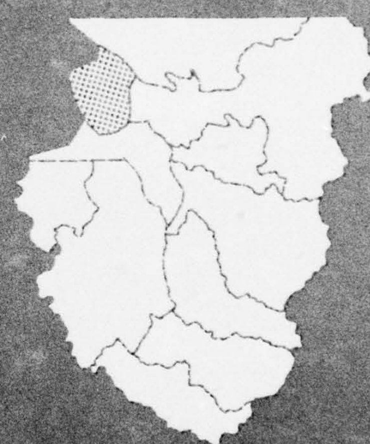
## Summary

Overbank flooding occurs on a frequency of about once every one to two years. Average annual flood damages are estimated to be $4,000 and the damages that would result from a flood with an estimated average recurrence interval of 100 years are estimated to be $51,000.

Future average annual flood damages are expected to increase in proportion to the increase in economic activity in the flood plain if additional protection is not provided. The trend of development within the basin would result in future growth of flood damages approximating 2 percent compounded annually without flood control and will result in future growth of annual damages to $6,000 in 1980, $9,000 in 2000, and $14,000 in 2020.

Reduction in flood damages could be accomplished by levee construction but the annual costs of these protective works would greatly exceed the resulting flood benefits. Flood plain management should be initiated immediately to insure that future developments on the flood plain are controlled.

# San Juan Islands



# SAN JUAN ISLANDS

There are no large streams or rivers in the San Juan Island Basin and overbank flooding is not considered a serious problem. Small watershed flooding and ponding problems in this basin are discussed in Appendix XIV, Watershed Management.

AD-A037 580 PACIFIC NORTHWEST RIVER BASINS COMMISSION VANCOUVER WASH F/G 8/6
COMPREHENSIVE STUDY OF WATER AND RELATED LAND RESOURCES. PUGET --ETC(U)
MAR 70 A T NEALE, S STEINBORN, L F KEHNE

UNCLASSIFIED NL

4 OF 4
AD
A037580

END
DATE
FILMED
4-77